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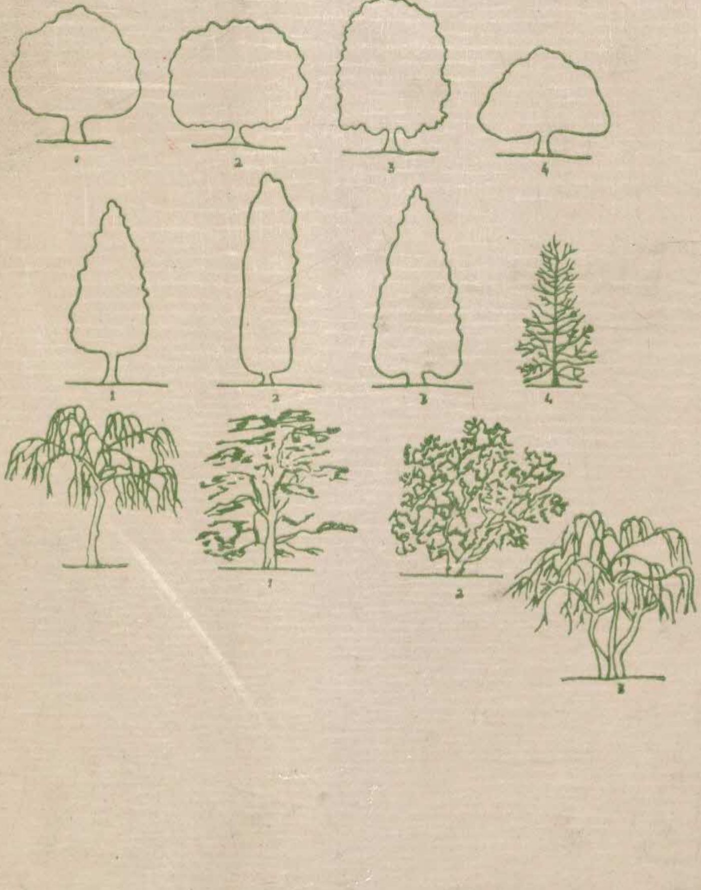
FOR
ENVIRONMENTAL CONSERVATION



RAJKUMAR GUPTA

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FOR
ENVIRONMENTAL CONSERVATION

Rajkumar Gupta

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परिचय

हमारे कृषि प्रधान देश की अर्थ-व्यवस्था तीन पापग्रहों-बाढ़, सूखा और रेगिस्तान के प्रकोप से ग्रसित है । सुधरे बीज, खाद और उत्तम सिंचाई व्यवस्था के द्वारा हम निश्चित रूप से कृषि उत्पादन बढ़ाने के प्रयास कर रहे हैं और उनमें सफलता भी मिली है, परन्तु बाढ़ और भूक्षरण से होने वाली ऊर्वरकों को ५३ लाख ७० हजार टन की वार्षिक क्षति के सामने जिसका मूल्य ७०० करोड़ रुपये कूता गया है ये प्रयास फीके पड़ जाते हैं । इससे भी भयंकर प्रतिवर्ष होने वाली मिट्टी की ऊपरी उपजाऊ पर्त को भूक्षरण से क्षति है। यह मिट्टी फिर वापस नहीं लौट सकती है । करोड़ों रुपये की पूंजी से बनाये गये बहुउद्देशीय बांध-जलाशयों और अन्य सिंचाई प्रणालियों के समय से पूर्व गाद से भर जाना दूसरा चिता का विषय है । ये तो कुछ प्रत्यक्ष दिखाई देने वाले चिन्ह हैं, जिन्होंने योजकों को धीरे-धीरे होने वाली, परन्तु भयंकर तबाही के कारणों को तह में जाने के लिये विवश कर दिया है । वायु और जल प्रदूषण के खतरों की ओर जो अब घनी आबादी वाले नगरों में दिखाई देने लगे हैं, वैज्ञानिकों और शोधकर्ताओं ने हमारा ध्यान आकर्षित किया है । इतना ही नहीं अक्षुण्ण माने जाने वाले हिम के भण्डार हिमानियां तेजी से पीछे हटते जा रहे हैं ।

बिगड़ते हुए पर्यावरण के लिए हमारी भोग प्रधान भौतिकवादी सभ्यता उत्तरदायी है, जिसने मनुष्य को प्रकृति के मित्र के बजाय प्रकृति का स्वामी और विजेता बना दिया, अधिकाधिक भोग की वस्तुयें जुटाना सभ्यता का चिन्ह माना जाता है और उसके लिए प्रकृति के भण्डारों का हमने मनमाना शोषण (दोहन नहीं) किया है । युग-युगों से धरती माता पुत्रवत् मनुष्य, पशु-पक्षियों और अन्य जीवधारियों का, जिसमें वनस्पति भी है, पोषण करती आई है । धरती पर मनुष्य, पशु-पक्षी और पेड़-पौधों एक दूसरे पर आश्रित रहकर सगे भाईयों के समान रहे, परन्तु जब मनुष्य की कभी तृप्त न होने वलीभोगलिप्सा बढ़ने लगी तो पशु-पक्षी और पेड़ पौधों का जीवन दूभर हो गया । हमने नये नये नगरों और सड़कों का निर्माण किया और जहां-जहां इनका विस्तार हुआ, पेड़-पौधे और पशु-पक्षी लुप्त होते गये । हमारे घने जंगल दैत्याकार कारखानों के पेट में समा गये । तथाकथित विकसित देशों में पर्यावरणीय संकट (Ecological Crisis) पैदा हो गया है, परन्तु सब

से दुःख की बात तो यह है कि विकासशील देश उन्हीं का अंधानुकरण कर रहे हैं और स्वयं महाविनाश की ओर अग्रसर हो रहे हैं। यह पागलपन इस कोटि तक पहुंच गया है कि वनों की रक्षा कर भूमि संरक्षण करने वाले संरक्षणवादियों (Conservationists) को, जो इन देशों में अल्पमत में हैं, प्रगति रोड़ा अटकाने वाले देशद्रोही तक कहा जाता है। परन्तु इन थोथे नारों के शोर के बीच इस शाश्वत सत्य (Eternal truth) को दबाया नहीं जा सकता कि किसी देश की वास्तविक संपत्ति उसकी मिट्टी है और मिट्टी के क्षरण को रोकने का कार्य ही वास्तविक देश सेवा का कार्य है। मिट्टी से अधिक कीमती कोई दूसरी वस्तु हो नहीं सकती और मिट्टी का कोई मोल भी नहीं हो सकता । सब प्रकार का विकास आखिर मिट्टी के ऊपर ही तो होगा।

हिमालय में वन विनाश के फलस्वरूप तेजी से होने वाले भूक्षरण के दुष्परिणाम प्रत्यक्ष दिखाई देने लगे हैं। मिट्टी की ऊपरी उपजाऊ मिट्टी की पर्त (Upper fertile layer of the top soil) बह गई है और प्रकृति विज्ञान का यह सिद्धांत कि मिट्टी के पीछे-पीछे मनुष्य भी नीचे की ओर भागते हैं, वहां के युवा शक्तिविहीन गाँवों में फलितार्थ दिखाई दे रहा है। केवल गाँवों से श्रम और बुद्धि शक्ति का पलायन नहीं हो रहा है बल्कि सारे देश के जल व उपजाऊ मिट्टी के भण्डार से अब नदियाँ बरसात में बाढ़ और रेत लेकर गंगा-यमुना के उपजाऊ मैदान को धीरे-धीरे रेगिस्तान में बदल रही हैं। इन नदियों के बहाव में बरसात और जाड़े के मौसम में भारी अन्तर होने के कारण इन पर आश्रित सिंचाई और पनबिजली योजनाओं की क्षमता कम होती जा रही है। इस गलती को सुधारने के लिए हम एक बड़ी गलती कर रहे हैं। भूकंपों के लिए संवेदनशील इस क्षेत्र में बड़े बड़े बाँधों की योजनायें बनाकर एक बड़े पर्यावरणीय संकट को न्यौता दे रहे हैं।

इन सब समस्याओं का एक ही उत्तर है। हम रहे-सहे पेड़ों का रक्षण करें और युद्धस्तर पर वृक्षारोपण का एक व्यापक कार्यक्रम प्रारम्भ करें। पेड़ों के रक्षण के लिए यह आवश्यक है कि आज की व्यापारिक वन नीति का स्थान, जो पेड़ को मुख्य पैदावार लकड़ी (timber) और अन्य औद्योगिक कच्चा माल मानती है, के स्थान पर जल और मृदा संरक्षण को महत्व देने वाली नई वन नीति लें। हिमालय में हममें देखा प्रत्येक हरा पेड़ बाढ़ और भूस्खलन के खिलाफ एक जिन्दा संतरी का काम करता है। हिमालय के पेड़ों की मुख्य उपज देश को जीवन देने वाला जल है और बढ़ती

हुई आबादी के साथ-साथ शुद्ध पेय जल और स्वच्छ प्राणवायु की आवश्यकता बढ़ रही है। इसलिए विश्वविख्यात वृक्षमानव (Man of tree) डा० सेंट रिचर्ड वर्बा बेकर ने कहा कि हिमालय के वन संरक्षित (Protection) वन घोषित किये जाने चाहिए और यहाँ से देश को मिलने वाली प्राणवायु (Oxygen) व जल के बदले इस क्षेत्र के विकास के लिये एक विशेषकर अन्य क्षेत्रों पर लगना चाहिए। इस क्षेत्र के वृक्षों से पूर्णतया आच्छादित हो जाने पर स्वतः ही जल संरक्षण होने लगेगा और वन प्राकृतिक बांधों का काम करेंगे, जहां से नदियों के जल प्रवाह में आई अस्थिरता कम होती जावेगी। जल संरक्षण और मृदा संरक्षण व निर्माण की सर्वाधिक क्षमता चौड़ी पत्ती वाले पेड़ों में हैं, अतः उनको हटाकर शंकुधर वनों व तराई क्षेत्रों के प्राकृतिक वनों को काटकर उगाये यूक्लिप्टिस के वनों के स्थान पर पुनः इन पेड़ों को उगाना होगा। मेरी राय में भारत को वृक्षारोपण के मामले में चीन का अनुकरण करना होगा। हमें कृषि को केन्द्रबिन्दु मानकर कृषि उत्पादन को बढ़ाने वाले पेड़ों को ही उगाना होगा, चाहे वे सड़कों पर छाया और पार्कों में सौंदर्यवृद्धि के लिये ही क्यों न हों। सबसे बड़ा सौंदर्य तो वह है जो मानवों को भूख से मुक्ति दिलाने में सहायक हो। अतः वृक्षारोपण का पाँच 'एफ' कार्यक्रम (Food, Fodder, Fuel, Fertilizer & Fiber) अपनाया जाना चाहिए। यह वैज्ञानिकों के शोध का विषय है कि किस भूमि पर इनमें से कौन सा पेड़ अच्छी तरह पनप सकता है। इन पेड़ों को उगाने में भी हमें यह ध्यान रखना होगा कि हम मिट्टी को बनाने (Soil builder) वाले और मिट्टी को सुधारने वाले (Soil improver) पेड़ों को ही बढ़ावा दें और मिट्टी को लूटने वाले (Soil depleters) पेड़ों को अलविदा दें, चाहे वे कितने ही बड़े औद्योगिक महत्व के क्यों न हों? मानव जाति को जिन्दा रहने के लिए सबसे बुनियादी उद्योग रोटी, कपड़ा और मकान की उसकी अनिवार्य आवश्यकताओं को पूरा करने का उद्योग है और धरती का पहला और न्यायपूर्ण उपयोग इन्हीं के लिए होना चाहिए। इससे धरती और मनुष्य के बीच के स्वाभाविक संबंधों—माँ और बेटे के सम्बन्धों की पुनः स्थापना होगी और मानव भोगलिप्सा की तृप्ति के लिए आज धरती का शोषण करके उसके साथ बलात्कार के जघन्य पाप व अपराध से मुक्त हो सकेगा।

डा० राजकुमार गुप्ता उन गिने-चुने वैज्ञानिक शोधकर्त्ताओं में एक हैं, जिनकी प्रयोगशाला समस्याओं से घिरे हुए गाँव और उनके निवासियों के बीच रही है। मेरा उनके साथ २० वर्ष पुराना परिचय है, जब वे हमारे छोटे से नगर में वनस्पति विज्ञान के शिक्षक के रूप में आये थे। उनकी शोधकर्त्ता वृत्ति ने तरूणों में शोध के लिए भूख पैदा की। वे स्वयं पहाड़ों

की परिस्थितियों का सूक्ष्म अध्ययन करते रहे और जब कई वर्षों के महत्वपूर्ण शोध कार्य के बाद वे देहरादून स्थित केन्द्रीय मृदा एवं जल संरक्षण संस्थान में आये तो उन्होंने टिहरी-गढ़वाल के फकोट के आसपास के ग्राम समूह को अपने व्यावहारिक कार्य एवं शोध का क्षेत्र बनाया। विज्ञान को जन-जन तक पहुंचाने का यह महत्वपूर्ण प्रयोग अन्य वैज्ञानिकों के लिए मार्गदर्शक का काम करेगा।

मैं बहुत उत्सुकता से उस दिन की प्रतीक्षा में हूँ जब व्यावहारिक जीवन की समस्याओं का समाधान करने वाली विज्ञान की खोजों को गांव का चैत-वैशाख (सामान्य आदमी) भी आत्मसात कर सके और अपना उद्धार स्वयं कर सके। इस दिशा में उत्तराखण्ड में ६ वर्ष पूर्व जन्मे 'चिपको' आन्दोलन ने महत्वपूर्ण कार्य किया है। आज लोकगीतों के द्वारा अनपढ़ महिलाओं के मुख से विज्ञान के ये सत्य शब्द मुखरित हो रहे हैं—

क्या हैं जंगल के उपकार ?
मिट्टी पानी और बयार (Oxygen)
मिट्टी पानी और बयार
जिन्दा रहने के आधार

और कलबलांदी डाली की पराण छाती से लगावा (जीवन से भरपूर पेड़ के साथ अपने दिल की धड़कनों को जोड़ो)।

वृक्षों के प्रति इस भावना की उदय हुए बिना उनका रक्षण और पोषण असंभव है।

मैं आशा करता हूँ कि डा० गुप्ता की इस उपयोगी पुस्तक का संशोधित और परिवर्द्धित हिन्दी व अन्य भारतीय भाषाओं का संस्करण शीघ्र ही प्रकाशित होगा और उसमें पेड़ों के वनस्पति विज्ञान के नामों के अलावा प्रचलित नाम भी होंगे। मैं इस महत्वपूर्ण ग्रँथ की रचना के लिए उनके प्रति आदर व्यक्त करता हूँ और कामना करता हूँ कि मानव जाति के रक्षक मूक वृक्षों के आशीर्वाद उन्हें मिलें।

सुन्दर लाल बहुगुणा
शिवानन्द आश्रम, डा० शिवानन्दनगर
टिहरी—गढ़वाल

दिनांक, १७ फरवरी, १९७९

Introduction

The economy of our country is influenced by three evil stars-flood, drought and desert. We are certainly trying to increase crop production and have succeeded also, through improved seeds, fertilizers, and better irrigation facilities. The damage caused by erosion, to soil fertility though is estimated at 53,700,00 tonnes per year costing approxomately 700 crore of rupees, making these efforts felt little. The upper soil layer is washed through soil erosion. This soil cannot be restored. Silting of various multipurpose reservoirs and other irrigation channels constructed at a cost of crores of rupees, is another thing to worry. These are some of the visible signs which have compelled the planners to go deep into the details of causes of the serious devastation. Dangers of water and air pollution, are now visible in densely populated cities. Not only this, glaciers have also started receeding.

Our materialistic civilisation is responding for environmental degradation which has made man Nature's Master and Conqueror instead of its friend; we over-exploited our natural resources for satisfying our requirements. Since ages, Mother Earth supported Man, Animals and other living beings including vegetation as her son. Man, animals, trees coexisted depending upon each other but when man exploited the resources for his limitless need, life of animals and plants got endangered. We planned new towns and roads and wherever we extended them, plants and animals got extinct. Our dense forests were cut to feed our factories; the so-called Environmental crisis developed. It is regretable that developing nations are blindly following the developed countries and themselves heading for devastation. Sometimes, the soil and forest conservationists who are in minority are branded as traitors, but the truth cannot be suppressed by mere slogans. The real service to a nation is to protect its soil. There cannot be anything valuable than soil and nobody can pay the price of soil-after all the development shall be on the soil.

The effects of soil erosion, as a result of deforestation in the Himalayas, are clearly visible. The top soil has been washed. The natures' principle that man follows the soil, is evident in the villages. The villagers are not being supported by labour and intelligence. The fertile soil of not only villages but the entire country, through floods in the rivers during monsoon, is gradually changing the fertile lands of Ganga-Yamuna into deserts. The capacity of hydro-electric power generation and irrigation is decreasing due to great difference in the flow of these rivers during monsoon and winters. We are making yet another blunder to correct this mistake, inviting environmental crises, by constructing large dams in this seismic zone.

There is only one answer to there problems. We should conserve the residual trees and embark on a large-scale tree plantation programme. For conservation of trees it is essential to reframe our present forest policy, which considers trees as timber, industrial raw material, and to a realistic policy emphasising on soil and water conservation. Every tree in the Himalaya is a guard against erosion and flood. The trees in the Himalayas primarily conserve water which is life saver to a country. The requirement of pure water and clean air are increasing with population explosion.

World famous treeman, Dr. St. Richard Barbe Baker stated that Himalayan forests should be declared as protected forests and a special tax should be levied for the development of the area since it provides clean air and water to the country. By fully conserving the natural forests in this area, automatically water will be conserved and forests shall work as natural dams thereby reducing the erratic flow in the rivers. The broad-leaved species effectively conserve soil and water and are to be encouraged with replacement of conifer forests and Eucalyptus in Tarai region. In my opinion, India should follow China in this matter. Considering agriculture as the focal point, we shall have to grow trees which improve agricultural production, even though these may be shade-bearing, roadside plantation or for ornamentation in the parks. The beautification which can relieve mankind from hunger is the biggest ornamentation. Therefore, five F's in the afforestation programmes should be followed. Selection of site specific tree is the only matter of research for scientists. We have to keep in mind that those plants which make the soil fertile are to be encouraged and soil depleters should be discarded even though they might be of great industrial value. The basic industries for keeping mankind alive are the bread, clothing and house and the justified use of mother earth should be first to provide these essentials. With this, the relation between earth and man, would again be established and mother earth could be free from exploitation.

Dr. Raj Kumar Gupta is one of the few scientists whose laboratory had been the village environment and its people. I know him for the last twenty years when he came to our small town as a teacher in Botany. His aptitude for research enthused many young people. He himself studied the environment of the hills and when after many years of his research work, he came to Central Soil & Water Conservation Research and Training Instt., he made Fakot, in Tehri-Garhwal District, the subject of his operational research. This is an important experiment of bringing science to people which would show way to many scientists.

I am eager for the day when an ordinary villager would be able to transform into his practical life the researches for the improvement of his lot. In this direction 6 years old, Uttarakhand born Chipko Movement has done special work. Today, even the illiterate rural womenfolk sings the following :

What are the uses of forests
Soil, Water and Air,
Soil, Water and Air,
the basis for life.

and synchronise the rhythum of the heart with the tree-full of life.

Without these emotions, conservation and nurturing of the trees is impossible.

It is hoped that the revised edition and translation in Hindi and other languages of Dr. Gupta's useful book shall be soon published including the vernacular names of common plant species. I express my regards to him for writing this book and hope that the benefactor of humanity-the mute tree will bless him.

(Translated from original)

Preface

Presently there is very little area in the country which is free from the hazards of erosion. About 5 million hactares of forest in the country are reported to have been deforested during the last 25 years. The basic reasons being increase in population, rapid increase in industrialization, urbanization etc. The arid and semi-arid areas suffer primarily from wind erosion, and with erratic rainfall from water erosion. Humid and sub-humid areas suffer from water erosion. It has been estimated that about 3.7 million hactare of land is under the ravines which is subjected to constant forces of erosion. Studies on the sedimentation rates of 17 major reservoirs have revealed that against an average rate of designed sediment inflow of 9.17 hactare metre per 100 sq. km. per year, these are receiving 29.3 hactare metre per 100 sq km per year which is 213% more than the desired rate. This is perhaps due to the fact that effects of late over-growth of human and livestock population accentuated the situation leading to increased use of both renewable and non-renewable resources.

The role of plants in Soil and Moisture Conservation, moderating influence on climate and environment, in promoting mutual understandlng, reducing floods cannot be ignored The vagaries of monsoons are not all due to the whims of rain God "Varuna". Perhaps man also contributed to the seemingly erratic behavior of the monsoon, particularly when it failed to make its advent in certain areas.

Presently nearly 45 percent of the geographical area in the country is under agriculture which contributes to 45 percent of the gross national production. 22 percent area is reported to be under the forest cover contributing to 1.5 percent of the G.N.P. (exclusive of unrecorded removal and development of associated industries). 15 percent of the area is under wastelands which do not contribute anything to G.N.P. In addition, there are lands classified as culturable waste, unculturable waste which need serious attention in addition to vast areas lying unattended along nala, riversides, railway lines, roadside, etc.

There is no short-cut to restoring to India its green wealth and heritage. People would have to keep on planting more and more trees with an awareness to protect and save them. Much of the prosperity of the nation depend on the extent of tree wealth and the peoples love for them. There is no alternative but to judiciously use our resources and protect the existing ones by planting more and more plants on every pareel of land.

It is hoped that this publication would provide answer to many questions as to where to plant, what to plant, when to plant and how to plant on a wide varietly of situations met within the country and make the programme success.

June 05, 1979 R.K. Gupta

Acknowledgements

I express my gratitude towards my colleagues of the French Institute, Pondichery, Central Arid Zone Research Institute, Jodhpur and Central Soil & Water Conservation Research & Traning Institite, Dehra Dun who gave me plenty of opportunity to diseuss with them various aspect of Soil erosion, land degradation and conservation measures with special reference to land and water for environmental protection. During my visits all over the country I had ample of opportinity to discuss with people on the role of plants for environmental conservation. I am grateful to various State Soil Conservation Departments. I am particularly grateful to Dr. K.G. Tejwani, Director, Central Soil & Water Conservation Research & Trg. Institute, Dehra Dun and Dr. N. Patnaik, Member (Agriculture), Flood Commission, Govt. of India for the valuable guidance and suggestions which I have recevied from time to time.

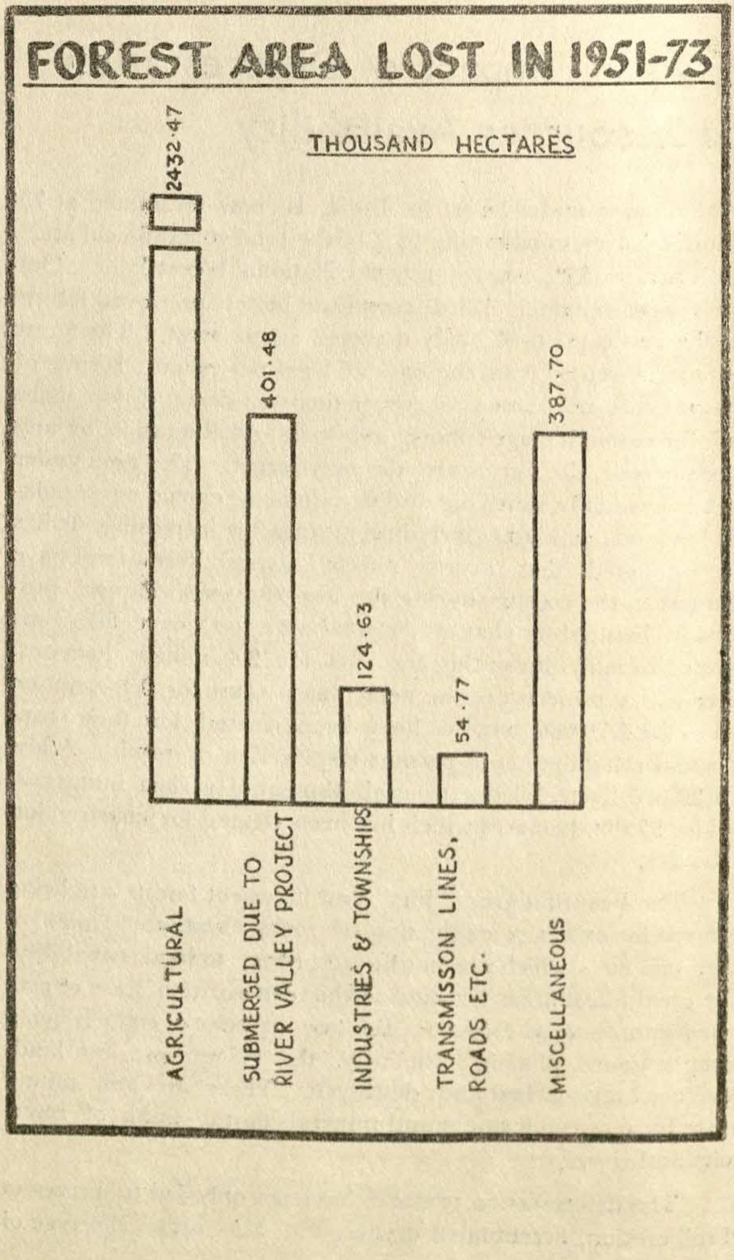
I am greatly indebted to Dr. M.S. Swaminathan, Director General, and Dr. D.R. Bhumbla, Deputy Director General ICAR, and my numerous friends, both within and outside the country, for the encouragement and inculcating in me a zeal to study various aspects of environmental conservation and management with respect to evaluation, assessment and planning of natural resources, watershed management practises and integrated landuse planning as a forcal point for rural development. To Prof H. Gaussen, Honorary Professor, University of Toulonse, France, Dr. P. Legris, Prof. G.S. Puri, Dr. M. Viart I owe my special gratitude for the valuable traning I have received at their hands which has been extremely useful in writing this book.

Ecological Impact of Deforestation and Resources Availability

The area under forest in India is now estimated at 75 million hactares, constituting 23% of the total geographical area. This is against 33% according to the National Forest Policy. Out of this approximately 1/3rd constitute better preserved forests and the rest consists of badly depleted scrub forest. The forest as shown in record is on the basis of legal possession. Inspite of such an acute imbalance, wherever there is demand for more land, for extending agriculture, industries, rehabilitation or any other purpose, the forests are the only target. The area under forest is gradually shrinking and demands of exploding population for forest products (including pastures) is increasing. It has been estimated that over 4 milion hactres of forest land have been lost to the country during the last 25 years. Figures provided in Table show that of the total area lost, over 50% was diverted to agriculture; this accounts for 2.4 million hactares. River valley projects are the next major cause for deforestation and so far 4,79,000 hactares have been cleared for these projects and rehabiliation of persons displaced as a result. A loss of 1,20,000 hactres is due to establishment of various industries, basides 57,000 hactares which has been cleared for construction of houses.

The beautiful grass "birs" and luxurient forests are being released for extensive cultivation on rocky situations, fringe of reservoirs etc., which are not fit according to land capability. The good forest areas left outside the demarcation lines of protected and reserved forests for the free exercise of right is being brought under plough. Similarly, the village grazing lands have been encroached and destroyed. There are still minng leases for quarrying stones and minerals on the bank of reservoirs and rivers.

The deforestation practises have not only led to processes of soil erosion, accentuated dryness but also acute shortage of



FOREST AREA LOST IN 1951-73

water, thus forming a vicious cycle (Fig.). The little good work on the fraction priority area under the various developmental activities does not have a significant effect on account of damage in extensive untreated areas.

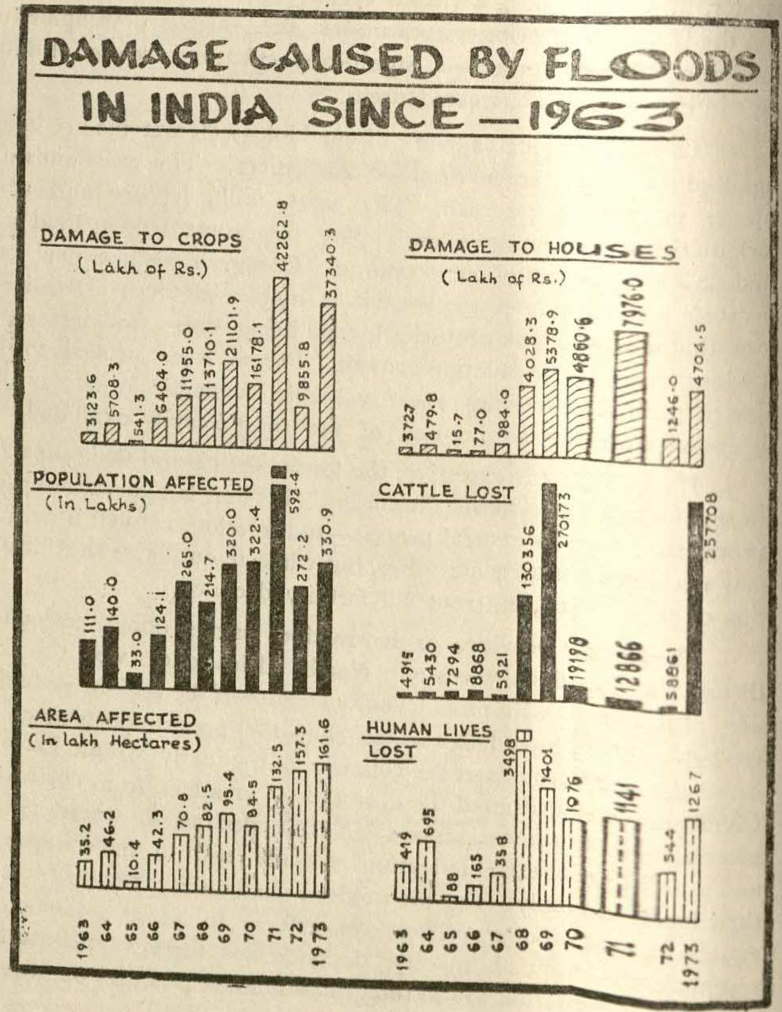
The carrying capacity of our biological systems are being ignored and exceeded more and more. The grasslands are under grazing pressure. The meat, milk, leather and wool originating from grasslands play important role in food and industrial sectors of our economy. Overgrzing is not new but its scale and rate of acceleration is unprecedented. Deterioration that once took centuries is now being comprised into years by inexorable population growth. Forests have proved to be one of the humanities most valuable economic resources and in consequence to be one of the most heavily exploited.

If cutting is excessive, the forests shrink and their capacity to satisfy human needs dimnishes. Erosion is undermining soil productivity. A natural process—soil erosion, as such is neither new nor necessarily alarming, but when it outplaces the formation of new soil, inherent soil fertility declines.

History provides us instructive lessons about ecological threats to national security. North Africa once was the granery of Roman Empire. Today fertility of the region is badly eroded soils, have fallen so low that the area imports much of its food. Accounts of the collapse of the early Middle Eastern Civilization attributed the downfall to invaders from north but more recently investigations link their decline to waterlogging and salinity of their irrigation systems and to the collapse of their food supply. For the modern community the prospect is equally threatening. Therefore, efforts to preseve biological systems on which humanity depends are urgently needed for which the solution lies in integrated landuse practises on watershed basis.

Impact on hydrological regime

Water being the potential ecological factor, controls the distribution and physiognomy of natural vegetation and *vice versa*. Rainfall is the main source of water supply and accordingly any change in the system through deforestation and other human influences affect the annual rainfall, its seasonal distri-



DAMAGE CAUSED BY FLOODS IN INDIA SINCE — 1963

DAMAGE TO CROPS (Lakh of Rs.)

DAMAGE TO HOUSES (Lakh of Rs.)

POPULATION AFFECTED (In Lakhs)

CATTLE LOST

AREA AFFECTED (In lakh Hectares)

HUMAN LIVES LOST

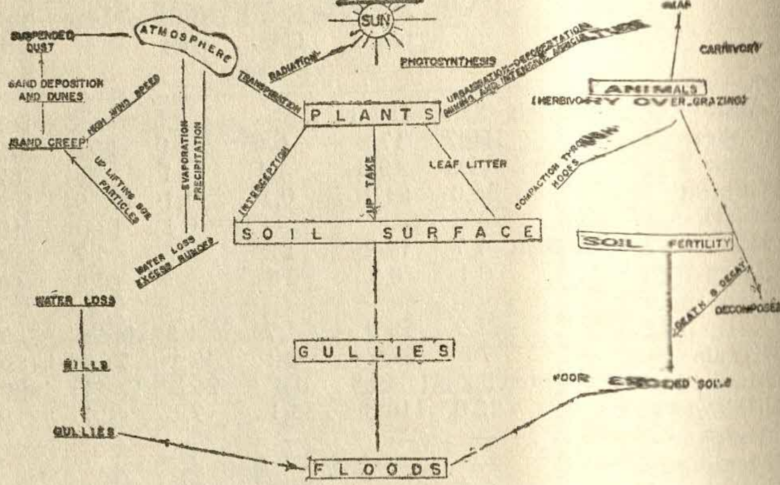
Table 0.0–Statewise Forest area lost for various purposes during 1951-52 to 1975-76 (000 hact)

States and U.T.	Forest area lost on account of RVP	Agriculture	Road Contruction	Industries	Misc	Total
Andhra Pradeseh	33.9	153.0	—	8.5	6.8	202.2
Assam	190.7	17.6	6.6	2.9	25.8	72.6
Bihar	1.3	43.3	1.1	11.1	5.8	67.6
Gujarat	35.0	21.1	0.3	1.1	122.9	180.4
Haryana	—	—	—	0.1	18.0	18.1
Himachal Pradsh	7.7	12.2	1.2	—	5.7	26.6
Jammu & Kashmir	0.1	0.3	0.2	—	90.2	90.8
Karnataka	81.3	73.5	1.7	1.5	144.4	308.4
Kerala	7.8	94.6	0.2	12.1	74.3	189.0
Madhya Pradesh	69.2	1,453.3	0.4	24.8	262.1	1809.8
Maharashtra	13.0	118.8	53.1	7.8	42.7	215.3
Manipur	—	—	—	—	—	—
Meghalya	—	—	—	—	—	—
Nagaland	—	—	—	2.0	0.1	2.1
Orissa	46.8	8.3	0.8	24.2	29.2	109.3
Punjab	—	0.4	—	—	8.1	8.5
Rajasthan	14.5	33.0	0.3	1.3	36.7	85.8
Sikkim	—	—	—	—	—	—
Tamil Nadu	14.5	6.6	—	—	13.0	65.6
Tripura	7.9	11.2	0.2	Neg.	19.7	39.0
Uttar Pradesh	93.5	83.8	4.6	19.4	20.5	221.8
W. Bengal	1.7	313.7	2.6	2.9	3.6	324.5
Total	479.00	2255.7	53.4	120.1	929.6	4037.8
Union territory						
Andaman & Nicobar	—	7.0	0.5	—	3.1	10.8
Arunachal Pradesh	0.1	26.3	0.4	7.1	6.1	40.0
Dadra & N. Haveli	—	0.5	—	—	—	0.5
Goa, Daman & Diu	—	71.4	2.7	—	1.0	21.1
Mizoram	—	—	0.1	—	—	0.1
Delhi	—	—	0.1	—	—	0.1

After Voluntary Action Dec. 1978,20 (12) : 29.

bution and intensities thus making perceptible changes in water infiltration rates of soils, interception losses and net precipitation, resulting in higher runoff, streamflow and soil loss (Gupta

GENERALISED MODEL OF ENERGY AND WATERFLOW IN A SUB-WATERSHED AS INFLUENCED BY MAN



1978). The vegetation provides an effecive and cheapest method of soil and water conservation. A protective cover at the soil surface dissipates rain and runoff energy. Vegetation is an excellent tool for yielding relatively siltfree runoff.

Table 0.1—Effect of landuse on runoff and soil erosion (after Tejwani & Mathur, 1972).

Landuse/soil type	Runoff as % of rainfall	Soil loss (tonnes/ha)
1	2	3
1. *Dhulkot* (Silty clay loam) Slope 9% Rainfall 1250 mm (3 yrs. av.)		
Grass cover (*Cynodon dactylon*)	27.1	2.1
Bare fallow	71.1	42.4
Bare and ploughed fallow	59.6	155.9
Natural grass	21.2	1.0
2. *Rahmankhera* (Alluvial soil) Slope 3.45% (3 yrs. average)		
Uncultivated fallow	—	1.87
Cultivated fallow	—	15.68

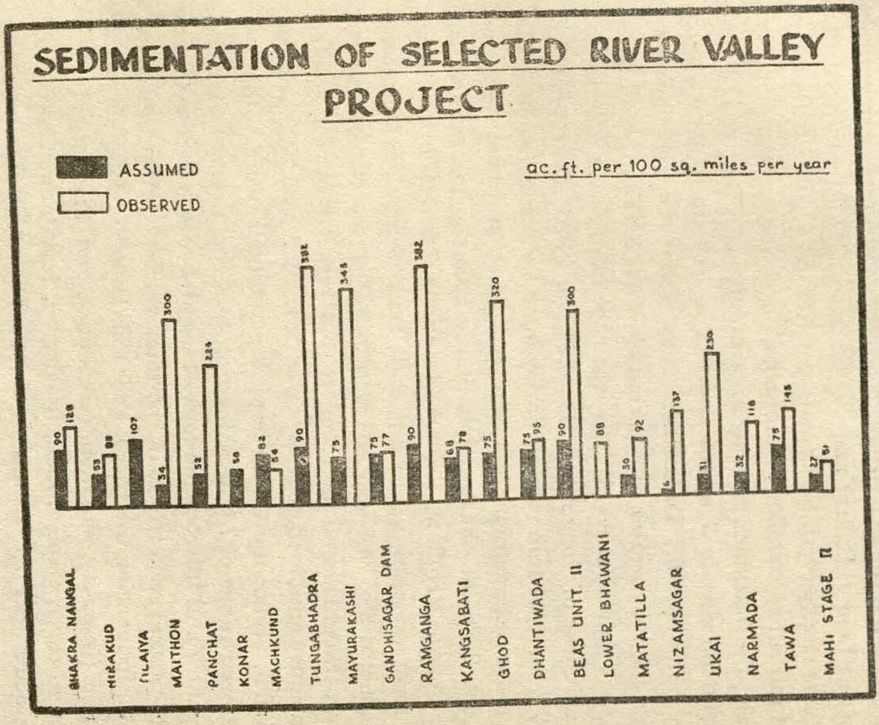
Contd.—

Sunnhemp buried	—	7.27 1% soil in runoff
Muug Tl	—	1.73
Cowpeas	—	1.95
Groundnut	—	8.61
Stylozobium	—	2.41
3. *Vasad* (alluvial soil)	slope 2%	Rainfall 791 mm
Natural fallow	2.1	2.0
Grass cover (*Dichanthium annulatum*)	1.0	1.5
Tobacco	26.0	4.8
Bajra	21.1	2 3
4. *Kota* (Black soil)	Slope 1%	Rainfall 657 mm (av. of 4 years)
Natural cover	0.4	4.9
Cultivated fallow	3.7	17.3
Jowar (kharif)	2.4	15.7
5. *Sholapur* (Medium black soil)	Slope 1.18%	Rainfall (607 mm av. of 9 years)
Natural fallow	4.8	1.3
Bare fallow	19.8	48.0
Shallow cultivation	22 5	60.4
Bajra and Tur (kharif)	16.5	57.9
Jowar (rabi, across slope	18.7	84 0
6. *Manjri* (Deep black soil)	Slope 3%	Rainfall 627 mm (av. of 5 years)
Bare fallow (weeds removed)	23.9	54 3
Cultivated fallow	25.0	87 0
Bajra kharif	14.8	87.5
Jowar rabi	16.1	60 5
7. *Ootacamund* (Laterite soil)	Slope 16%	Rainfall 1340 mm (av. of 4 years).
Eucalyptus globulus	1.1	0 02
Shola forest	1.3	0.06
Grassland (protected)	0.02	—
8. *Deochanda* (Red soil)	Slope 5%	Rainfall 1302 mm (av. of 3 years)
Natural fallow	9.5	—
Cynodon plectostachys	33.5	—
Pennisetum polystachyum	29.0	—
Maize	28.9	—
Ground Nut	19.9	—

Studies carried out at various places in the country have simply demonstrated that the natural fallow (ie. grass and shrubs) or grass alone give the least and negligible runoff and soil loss. Cultivated fallow give the maximum and dangerous rates of runoff and soil loss irrespecive of the slope, climate and soil conditions. The data recorded has been summarised in the table (after Tejwani and Mathur 1972). In the semiarid tracts of Rajasthan Bajpai *et al* (1975) showed maximum soil loss on bare soil. The cover of *Pennisetum purpureum* and *Vicia catajung* reduced soil loss on slopes 0-2% while *Cenchrus ciliaris* reduced soil sloss at 4% slope. Significantly greater soil and water losses were recorded from bare plots as compared to those covered with vegetation. The lowest water loss was recorded with blue panic (*Panicum antidotale*) whereas the loss under *C. ciliaris* was maximum.

Different vegetative covers differ in their effect on interception of rain and runoff yield. The role of forests on moderating high intensity storms and safe water disposal is well known. Forests not only interept the rainfall, through their canopy cover and reduce direct impact of raindrops on the soil but also increase the water stable aggregates and improve water infiltration capacity of the soil. Ghosh and Banerji (1974) studied six soil profiles from a mixed deciduous area of north-west Bengal and showed that highest amount of waterstable aggregates are in the top soil (0-15 cm). Positive correlation exists between the organic matter as well as clay content with water stable aggregates. A change in the forest vegetation normally leads to a change in the nature of soil and especially in the type of humus (Puri and Gupta 1951), particularly the lignin/Cellulose ratio of organic matter. Undisturbed forest soil is more pemeable than forest soil consolidated through cattle, vehicles and dragging of logs. This is usually harmful since it reduces the pore space and consequently the infitration capacity of the soil thus reducing water percolation. Once the soil is compacted, it is prone to runoff and erosion. Regeneration is not easily established and roots can not penetrate in highly compacted soil. This has been considered as one of the causes for poor *Abies* regeneration in the Himalayas (Puri and Gupta 1968).

The canopy eover of forest vegetation intercepts the rainfall. The raindrops are reported to have an energy of 110 HP on an acre during a rainfall of 0.1 inch per hactare. (Yadav



SEDIMENTATION OF SELECTED RIVER VALLEY PROJECT

1961) which is considered sufficient to lift 7 inches (17.5 cm) of top soil layer to a height of 3 inches (12.5 cm) during a rain of one hour. Dabral and Subba Rao (1969) estimated that *Shorea robusta* (vern Sal) conducted 7.2, 54.6 and 38.2 pereent of rainfall as stemflow, throughfall and interception respectively, the maximum number of trees ranging between 17.8-30.5 cm diam class in *S. robusta* and 10.2 to 20.3 cm diameter range in *Acacia catechu*. In another study Dalal *et al* (1976) showed that the interception of precipitation in *S. robusta* was high in case of light showers (37.3%) when the rainfall was 4.2 mm and low in case of heavy showers; 4.1% for 140.3 mm rainfall and 4.7% for 63.4 mm rainfall acompanied by strong winds. The average interception loss was estimated at about 14% and about 3.6% of the precipitation is recorded to have reached the floor as stemflow. Dabral and Subba Rao (1968) estimated in *Pinus roxburghii* (vern Chir) and Teak plantations that Pinus conducted 3.6, 74.3 and 22.1 percent of gross rainfall as stem flow, throghfall and interception loss respectively for rainfall amounts considered together was 3.3, 69.7 and 27% of gross rainfall. Since most trees in pine plantations were within the diameter range of 7.6 to 22.9 cm it may be assumed that the stemflow and interception losses ranged between 2 to 3.9 and 2-24 percent respectively of the total rainfall. Other important factor influencing the runoff and soil losses in addition to the rainfall (intensity, duration, distribution and amount) are the ground cover, slope of land, its degree, length and aspect) soil characterstics etc. Tejwani *et al* (1975) recorded that interception by crowns of Acacia species varied from 15.5 to 26 percent of the total precipitation. Out of the 3 species of Acacia (*A. nilotica* ssp. *indica*, *A. modesta* and *A. catechu*) *A. nilotica* had the maximum interception (26% of rainfall) followed by *A. modesta* (21.2%) and *A. catechu* (15.5%). Similarly, grass covers provide good soil protetion. The following table records the effect of grass covers on runoff and soil loss.

Table 0.2 Effect of defferent grasses on runoff & Soil loss. (after Anonymons 1955-1960)

	Runoff (% of P)	Soil loss Kg/hact
Cynodon plectostachys	35	56
Cenchrus ciliaris	33	137
Panicum antidolale	36	67
Pennisetum polystachyum	27	67
Urochloa stolonifera	32	78

On 11 percent slope, runoff and soil losses were reduced under different grass/legume covers like Kudzu, *Dichanthium annulatum*, *Chrysopogon fulvus* and *Eualiopsis binata*. The date adapted from Tejwani *et al* (1975) is recorded in table below.

Table 0.3 Percentage runoff and Soil loss under defferent covers.

	Pueraria hirsuta	Dichanthium annulatum	Chryso progon fulvus	Eulaliopsis binata
Runoff as % of rainfall	1.8	1.9	2.5	5.2
Mean (1961-66) ranifall-603	11	11.3	15.0	31.5
Soll loss in Kg/h	108	228	295.0	290

From this table it may be seen that all the covers provided protection to soil; runoff and soil loss were both minimum under Kudzu. Kudzu should therefore be preferred where reduction of runoff, soil loss is the main object, while for good water yields *Eulaliopsis binata* will be good. Grasses with dense growth habit particulary at the ground level reduce both runoff and soil loss better than grass of open and luxuriant growth.

Data from the Siwalik region indiated (Tejwani *et al* 1975) that runoff decreased by over 300 percent with contour trench and afforestation while with burning, cutting of trees, shrubs, overgrazing and overgrazing alone increased runoff to the extent of 20.3, 72.9 and 23.4 percent respectively. The peak rate of discharge decreased by 72.7 percent which the

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P=Precipitation

watershed is treated with contour trenchces and afforestation. Due to burning, cutting of trees, shrubs and overgrazing and overgrazing alone, peak discharge decreased by 69.2, 34.0 and 32.0 percent respectively.

Studies on two small brush watersheds at Dehra Dun (Mathur *et al* 1976) showed that during the callibration period (1961-68) a watershed W1F (1.45 hact) gave 18 percent more runoff and 63% higher peak rate of runoff as compared to W2F (0.87 hact) when W8F was clearfelled and reforrested with Eucalyptus. The post callibration relationship indicates that W1F (treated) after afforestation gave 10% runoff and peak of runoff as compared to W2F (untreated). The total reduction of 28 percent in runoff and 73 percent in peakrate is due to afforestation resulting in fully stocked plantation and a dense under growth (Mathur and Sajwan 1978).

Among the Himalayan states Jammu and Kashmir, Himachal Pradesh and pilgrim centres in Uttarakhand earn a substantial revenue from tourism and orchards. The forests are cleared for fuel, timber and for agricultural uses. *Quercus incana* and other oaks are the major species exploited for charcoal, fuel, leaf fodders and as material for thatching houses and cattlesheds. These forests are managed as production forests rather than as protection forests. Ecological succession of oak-conifer forests has been studied from Kashmir to Garhwal (Mohan *et al* 1956, Mohan and Puri 1956, Mohan *et al* 1957, Puri and Gupta 1951, 1968, Puri and Mani 1957, Gupta 1959, 1960, 1964, 1966, Gupta and Singh 1962 and Wali 1964). In the lower, middle and uper elevations oaks (*Q. incana*, *Q. dilatata* and *Q. semecarpifolia*) are the climax communities. The conifers or mixed oak-conifer communites over large areas are the result of special soil and biotic features. Some of the conifer communities appear to be "seral" in nature, showing a secondary succession to the oak-conifer forests and are preserved in their present state due to peuliar bio-edaphic factors present in the region (Gupta 1960).

Progression of these communities under the existing conditions of oak climax is very slow. In high altitudes, the stable climax forest of oak is disturbed by coppicing, lopping and grazing etc., resulting in the formation of a number of mixed oak conifer communties which represent a secondary succession tending to develop to pure oak community. Similarly the climax vegetation in India, as has been indicated by Puri (1960), appears to be evergreen. The adverse biotic factors in the hilly regions on the dip slopes bring into prominance a "seral" stage of *Pinus roxburghii*, *Picea* and *Populus* community. Open grassy communties and a pure *Pinus wallichiana* community in the glacial regions on morains is also considered to be biotic and their progression to Abies is much faster on dip slopes than on scarp slopes. In the middle zone, pure forest of *Q. dilatata* is rare, while conifers especially *Cedrus deodara* form the 'seral' stages. In the lower levels, forest of *Q. incana* is considerd to be a stable climax which after disturbance invites conifers like *P. roxburghii* and sometimes *Picea* depending upon the extent of interference and potentiality of the soil. In areas where oak has been completely destroyed and which have been put under cultivation and subsequently abandoned *Pinus roxbrghii* dominates. In places where oak has been lopped and cut heavily a secondary oak scrub develops. The *Pinus roxburghii* community on quarzite and other rocks is at some places a degenerated type of scondary succession too. These observations are very important in view of the largescale degradation of the Himalayan environment and suitability of chir for reffotestation in the region which has recently been focussed because of large scale floods and socio-economic disparity in the Himalayan regions with the rest of the contry.

Infiltration of water under different forest covers varies considrably depending upon the condition of the forest floor. *Shorea roubsa* forests with good leaflitter have been recorded to show high infiltration rates (Patnaik and Virdi 1962). Besides productivity of forest stands, the growth and development of the ground flora and the amount of litter production has a direct bearing on the impact of raindrops on the soil. Since the presence of abundant leaflitter on the forest floor results in high infiltration rates efficient management of forests is aimed at conservation of leaflitter, on forest floor. Estimates of leaf litter have been made by Puri (1953-54), Srivastava *et a*

(1972), Dabral *et al* (1963) and others. Shorea forests at Dehra Dun show abundant leaf litter during March-May and no leaffall during July-December, the same is the case in chir forests. Interception values are higher with lower amounts and intensities of rainfall. Though data on the amount of interception, infiltration and leaflitter production from oak and oak-conifer zone is not available it can be presumed that oaks being broad-leaved produce more leaf litter than conifers. This might probably explain the better soil moisture conditions in the oak region as compared to conifer forests. Burning of leaflitter and its removal for manure is a common practise in the hills which results in low soil moisture percentage. The soil has a better moistute regime when the litter is burnt and not removed. The erosion is maximum when leaflitter is removed (2.73 cm splash as against 0.21 cm) when litter is not removed. Burning and removal of leaf litter also effects the organic carbon status and pH of the soil. There is a definite lowering of organic carbon status in the soil when the leaf litter is removed. The following table 0.4 records the effect of burning and removal of leaf litter on soil moisture (adapted from Tejwani *et al* 1975).

Year	Soil moisture % in 23 cm of top soil. Leaf litter not removed	Leaf litter removed from site	Leaf litter burnt
1960	14.01	11.80	3.36
1961	14.61	10.51	13.48
1962	16.98	13.10	14.83
1963	13.15	9.53	10.93

Average calculated from measucrements during the whole year
(1960, 8 data, 1961, 7; 1962, 6; & 1963, 6)

Maximum effect of fire is seen in lower elevations and plains where driest conditions prevail. Sometimes the forests are set to fire with the aim of getting fresh grass cover for grazing during critical periods before monsoons or collection of seeds such as Sal and Mahua. However, no regularity and method is followed. General studies on effect of fire on the forests have been made by Champion (1936), Osmaston (1920, 1914) and Gupta (1960). In dry years fires are exprienced in dry deciduous forests and conifers which are likely to produce dry soils and *vica versa* dry soils are likely to encourage fires. If the average physical characters of the soil and nature of the underlying rock in chir forests is compared with those in the adjoining oak forest, there would hardly be any marked difference. The pine forests are kept in equilibrium by the action of periodic fires which are the result of biotic influences.

Prevelant grazing systems cause deterioration of top soil by trampling through compaction and detachment of the top soil. With extensive grazing perennial palatable species become less dominant, give place to annual, less nutritious and less palatable species. The production under three systems of managament viz. 12 months closure, 6 months closure followed by grazing for 6 months and open conditions respectively is recorded 3.32, 2.89 and 0.16 mt/hactares of air dry forage at Bhatta Mussoorie hill while the conditions of runoff and soil loss are as follows. 0.5

Grazing systems	Runoff %	Soil loss in Kg/h.
Overgrazed	27	2340
Properly grazed	19	780
Ungrazed	11	390

(after DVC report 1955-60)

Dryland ecosystems in general and arid and alpine ecosystems in particular are fragile. Destruction is quick and easy but restoration difficult. Natural restoration rates are estimated to range 200-1,000 years. The time required for recoupment is directly associated with ecosystem degradation. Little of the dry region is under populated and parts overpopulated which appear to have never existed in equilibrium with the environment. Exploitive overuse is wide spread. Continued over-grazing and browsing promote ecosystem destruction and desertification.

Irrigation projects, by changing the primary productivity rates of the area markedly influence the population structure and thus a whole series of native consumer species. Those who can not tolerate the change become locally extinct. This leads to an ecologically oriented development principle as Dregne (1970) pointed out that "the facile belief that all the arid regions need to solve their problems is water" is no longer widely accepted. Strong winds, solar rediation will be the economic problems and will be there, whether the supply of water is small or large. The irrigation of a calcareous soil does not make it into a humid region soil. At best the limitless water turn the arid region too shallow, too steep or too salty to be used for anything except the production of sparse flora or fauna for similar developments.

Impact on Soil Properties

Extensive root system of forest vegetation including herbaceous flora has enormous capacity to bind the soil particles. Ultimately, the land under permanent vegetation cover on sandy soils show improvement in waterstable aggregates (Basu 1953; Chatterjee and Sen 1964, Sinha and Chatterjee 1966 and Singh & Chatterjee 1968). The differences in waterstable aggregates are primarily due to the soil binding capacity of roots and the extent of organic matter aded to the soil by different vegetation types. The root content of different grasses ultimately makes the difference in the organic matter content added to the soil and the crumb stability as shown below :

Table 0.6—Root content in quintals per hactare under permanent grasscover (after Sinha & Chatterjee 1968).

Grass	Months	Soil depth in cm.						Total
		0-15	15-30	30-45	45-60	60-75	75-90	
1	2	3	4	5	6	7	8	9
Chloris gayana	March	21.83	2.65	1.73	1.12	0.66	0.96	28.95
	May	19.77	4.58	2.59	3.38	1.89	1.16	33.37
	Sept.	25.49	2.50	1.45	1.03	0.77	0.79	32.03
Brachiaria brizantha	March	44.44	4.58	4.14	2.89	3.05	1.25	60.35
	May	45.42	8.37	9.36	5.85	3.49	2.26	74.75
	Sept.	54.43	4.73	2.48	1.49	0.79	0.57	64.38
Dichanthium annulatum	March	8.15	3.13	1.71	1.36	1.07	0.48	15.90
	May	12.91	1.76	1.40	2.03	0.90	0.94	19.93
	Sept.	16.60	1.99	1.80	1.21	1.16	0.92	18.68

Dichanthium caricosum	March	15.56	2.63	1.32	2.15	2.26	1.71	25.63
	May	19.07	2.28	2.02	3.05	2.32	1.93	30.63
	Sept.	25.62	4.10	3.79	3.73	0.72	1.12	39.08
Heteropogon contortus	March	10.52	3.18	1.82	1.38	0.72	0.68	20.30
	May	14.55	6.14	1.95	2.28	2.21	1.03	28.16
	Sept.	16.53	3.84	2.28	1.60	0.09	0.09	26.05
Pennisetum polystachyum	March	18.81	2.48	0.94	0.90	0.68	0.59	24.40
	May	21.68	2.45	1.14	1.32	0.79	0.79	28.08
	Sept.	29.85	11.66	3.24	2.41	1.42	1.38	49.96

CD @ 5% compared for	Grass	Depth	Grass/depth
March	2.104	1.775	5.129
May	1.819	1.556	4.471
September	1.600	1.380	3.902

Soil fertility : Studies on the effect of improved management of dune soils through afforestation is of considerable interest. Aggarwal *et al* (1976) found that soils under various tree species contained 241-356 kg/ha of available nitrogen as compard to 203 kg/ha in soil devoid of tree cover. Beneficial effect was also observed in Phosphorous and Potassium. Distribution of available nutrient status uuder perennial grass by Dhir and Gajbhiya (1973) showed that soil under and close to clump of grass has far higher content of various nutrient elements. The results further confirm that improved silvipastoral practises are not exploitative but help to build soil fertility.

Benefit of grass crop in tropical countries have been stressed by Theron (1955), Mandal (1955) and Sinha and Chatterjee (1966). The effect of a three year oldgrass plot under a cut and carry system on yield of Maize and Ground nut crop was studied by Sinha and Chatterjee (1966). The nitrogen reserves, organic carbon and waterstable aggregate content of soil were higher under grass plot than in ploughed up fallow plot. Maize yield showed a close correlation with total soil nitrogen, mineralised nitrogen after incubation for 20 days and water stable aggregate content while the goundnut yields showed a close correlation only with waterstable aggregates. Turnover values in grasslands indicate that 50-54 percent of root systems are replaced every year (Singh and Singh 1967).

Infiltration rates under various landuses show (Tejwani *et al.* 1975) that under agriculture, infiltration rate is lowest while under woodland it is the highest.

Table 0.7 Infiltration rates under different landuses.

	Average infiltratration rate in cm/ha		
	1st hour	2nd hour	3rd hour
Cultivated bottom land in valley	3.70	1.94	1.91
Cultivated in Himalayan upland	8.32	4.62	4.69
Shorea forest (Himalayan upland)	5.87	3.78	3.53
Shorea forest (Siwalik)	4.00	2.04	2.09

(after Tejwani *et al* 1975)

The infiltration rate in the forests, however, vary considerably depending upon the condition of the florest floor and the extent of biotic influences. The presence of abundant leaf litter results inhigher infilteration rates (Patnaik and Virdi 1972) as shown earlier. Shola forests, Broom and Blue gum plantations of 0tacamund recorded much higher infiltration rates than grasslands which are grazed (Tejwani *et al* 1975). Once the soil is compacted, it is prone to runoff and erosion as stated earlier but sometimes the compaction is useful in increasing growth of vegetation through contact of soil particle with the plant root. Thus, when moisture is limited, aeration is adequate, a certain amount of compaction may be useful.

Krishnaswamy *et al* (1951) while discusing the temperature differences in plantation and open sites concluded that forest cover seems to exercise moderating influence on temperature. Diurnal fluctuations are significantly higher in open than under forest covers and that the bare ground is heated more rapidly than the ground under forest cover. Water percolates through the soil in open conditions much earlier without being used, while under plantation, this rapidity of of percolation is very much checked by interception of forest canopy and absorption of water by roots.

Floods and Droughts

Floods and droughts are the two facets of the same coin of land mismanagement and soil erosion. The excessive runoff from the land deprive soils of the miosture which would otherwise be used for production from land. Similarly concentration of the same water down stream causes floods. This vicious cycle of droughts and floods need be broken with appropriate action including restoration of vegetation cover on denuded lands. The following table gives the extent of degrade lends in the country which needs immediate attention. (after J.S. Bali 1978)

i	Total geographical are a millon hactares			NCA
ii	Area subjected to serious	328.0		NCA
	wind and water erosion	150.0		NCA
iii	Area at critical stage of deterioration due to erosion	69.0		NCA
iv	Area subjected to wind erosion	32.0	whach	NCA
v	Area under sand dunes	7.4	,,	NCA
vi	Area under ravines	3.7	Min of A & I	
vii	Area affected by shifting cultivation	3.0	,,	,,
viii	Area affected by water logging	6.0	,,	,,
ix	Area under saline alkali soils	7.0		,,
x	Area liable to floods	25.0		C W C
xi	Drought prone area	56.5	Mino of A & I	

The problem is dynamic and every year about 8000 hactares of land is recorded to be further effected by ravines. As Vohra (1978) indicated that it is not possible to compute the loss in terms of money and calamity sufferd by the community on these accounts certain estimates have been made (Vohra 1974). Erosion is estimated to cause displacement of 6000 million tonnes of fertile top soil every year, supposed to

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1 NCA=National Commission on Agriculture

2 CWC=Central Water Power Commission

contain over million tonnes of NPK alone. At todays price it would cost over Rs. 1000 croers to replace. The loss of storage capacity of existing reservoirs caused by excessive siltation is extensive on which over Rs. 5000 crores have been spent on major reservoirs only. Siltation rates of some major reservoirs are given below (Soil conservation Digest 1974) as a consequence of which the damage is not only confined to soil productivity but increased floods, chocking of rivers through rise in their beds etc.

Once these reservoirs are silted up it will effect our power and irrigation potential. Floods cause on an average toll of about Rs. 300 crores every year by way of damage to crops, cattle, habitation, apart from indescribable distress to human beings. The value of land lost is well over Rs 10,000 crores on account of flooding and water logging thus bringing sizable area out of production. To all these losses much be added those which are being incurred as a result of our failure to make use of the capacity represented by vast areas of denuded non-agricultural land. Only about 30 million hactares out of 65 million hactares classified as forest land have adequate cover. About 95 million hactares represent more or less denuded land surface which not only has no production to the national income but are source of soil erosion. Therefore, a permanent vegetal cover could stop further erosion and at the sametime enable sun energy to be harnessed in Natures own way over nearly one third of our land surface. The restoration of vegetal cover would permit a greater proportion of rainwater to be infiltrated into the soil and improve the ground water potential through maximum recharging of ground aquifers. This would also help in moderating river flows, reducing them in peak season.

Agro-Forestry Techniques

The primary aim of these techniques is the production of food and the conservation and rehabilitation of soil resources needed for future food production. Growing population pressure combined with increasing pressures on limited areas of fertile soil might make food situation precarious. Revitalisation of our rural areas with better utilisation and management of

Table 0.8 Sediment data on River walley Projcets taken for Watershed management (after Soil Conservation Degest 1974) extracted from Hand Book of Sedmentation, New Delhi 1973

Name of RVP	Period of watershed manage-inception	Net catchment area in Sq miles	Disigned sediment inflow rate ac ft/100 sq. miles/year	Present Sediment yield ac. ft./100 sq. miles/year	Capacity coss	Ac/ft Dead
Mach Kund	2nd 5yr plan	755	82	66	5,80,000	5,700
Mayurakshi	3rd ,,	692	75	345*	4,93,000	53,000
Chambal (Gandhi Sagar)	-do-	8445	75	77	52,78,000	6,75,000
Ghod	-do-	1401	75	320	1,75,000	57,000
Dhantiwada	-do-	1105	75	95	3,76,000	66,000
Kangsabati	-do-	1460	68	78	9,20,000	1,20,000
Tungbhadra	-do-	10,735	90	382	30,53,000	53,000
Bhakra	2nd ,,	21,960	90**	129**	75,75,000	16,65,000
Kundah	3rd ,,	487	NA	AA		
Hirakud	-do-	31,900	53	76	66,00,000	18,80,003
Ramganga	-do-	1,180	90	369	19,86,000	2,06000
Madhon Panchif	2nd ,,	2010 & 3790	34,52	300, 226	11,00,000 12,82,000	1,63,000 1,92,000
Pohru	3rd ,,	—	--	—	—	—

Contd.

Nagarjun Sagar	4th 5yr plan	83,000	NA	75	93,70,000	—
Nizam Sagar	-do-	7,152	6	137.5	6,82,000	94,000
Pochamped	-do-	35,029	NA	NA	25,70,000	11,50,000
Ukai	-do-	24,025	31	230	69,00,000	
Matatilla	-do-	7955	30	92	9,16,000	280,000
Mahi Stage II	-do-	9,780	27	51.4	13,75,000	3,20,000
Loueer Bhawani	-do-	1,622	NA	88	7,50,000	20,000
Beas Cent II	-do-	2,635	90	300	65,50,000	10,50,000

*Sediment rate for 1965-70 is 478 ac ft/100 sq m/year

**Information leased from Sediment Sudies on Bhakra reservoir 1970-71 published by Management Board Nagal Town.

land resources, employment potential and higher productivety from land will help to solve problems of fire wood, nutrition, employment and degarded environment apart from prolonging the life of our reservoirs and hydel projects. The three dimensional ferestry practises would go a long way in environmental conservation and management since it fits into the natural biological cycle of our society. It would also provide a firm foundation to our Integrated Rural Development Programme (IRD). Greening of India to save our soil from further erosion, to put our idle lands to work and to get every hactare of our land to yield the very best it can is the only answer. This would also provide jobs for the millions through development of cottage industries such as basket making, drug farms, aromatic oils, cheap furniture, fibres, dairying, wool and meat production apart from food processing industry and nursery raising where landless could be absorbed after aquiring some skill. This would require an infrastructure at the village level to provide the credit and marketing facilities and coordinating facility at District, State and National, level. Plants suitable for various sites and purposes such as multipurpose trees, fodder fuel wood have been discussed in these pages for various habitats and agro-ecological zones. However, there is, in general, a shortage of trained man power in the field of agro-forestry. Though certain trees like *Acacia albida* and *Prosopis cineraria* are reported to compete with crops for nutrients or moisture, management of multipurpose tree cash crops need immediate attention since the scope is unlimited in tropical upland ecosystems which are being subjected to increased land use pressure through both growth of local population and migration from low land area. Since erosion in the uplands can result in low land crop losses through droughts and floods, inpeded drainage and silting of irrigation channels and re-ervoirs the industrial development could be seriously affected.

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Planting and Saving of Trees for Ecological Regeneration

Current awareness of the environmental degradation and the need for its improvement has been felt both by politicians, administrators and scientists. National Programme of Planting and Saving Trees has given a boost to the Vana Mahotsava started by Late Shri K.M. Munshi. If the number of seedlings planted during the past two decades are taken into consideration, there would be no room for the current anxiety. The trees are generally planted to achieve the targets fixed by the authorities without having regard to their adaptability, ecological parameters of the site conditions vis-a-vis their growth and population density. Hence the survival percentage is very low and majority of the plants die a natural death within a short period of their planting. Sometimes these are damaged or eaten away by the bovine population if they are not properly protected and fenced. The present note has been prepared with a view to provide technical information required regarding the suitable species for various habitats, nursery techniques and planting methods. The information is based on personal observations made by the author at various places in the country and literature available and referenced at the end.

THE ECOLOGICAL REGENERATION

Why should we plant trees ?

1. *Plants as social symbol and an aesthetic object*—Strong connection between social class and vegetation patterns has been described (Schmid, 1973). Plants of front yards like the exterior appearance of a house cover information about the persons within. Similarly, weeds give public notice that a landowner is unwilling to contribute to public decency. Though urban plants as ornaments change with time, particularly plantings persist in both private and public landscapes long after the fashion has changed. In some of the gardens

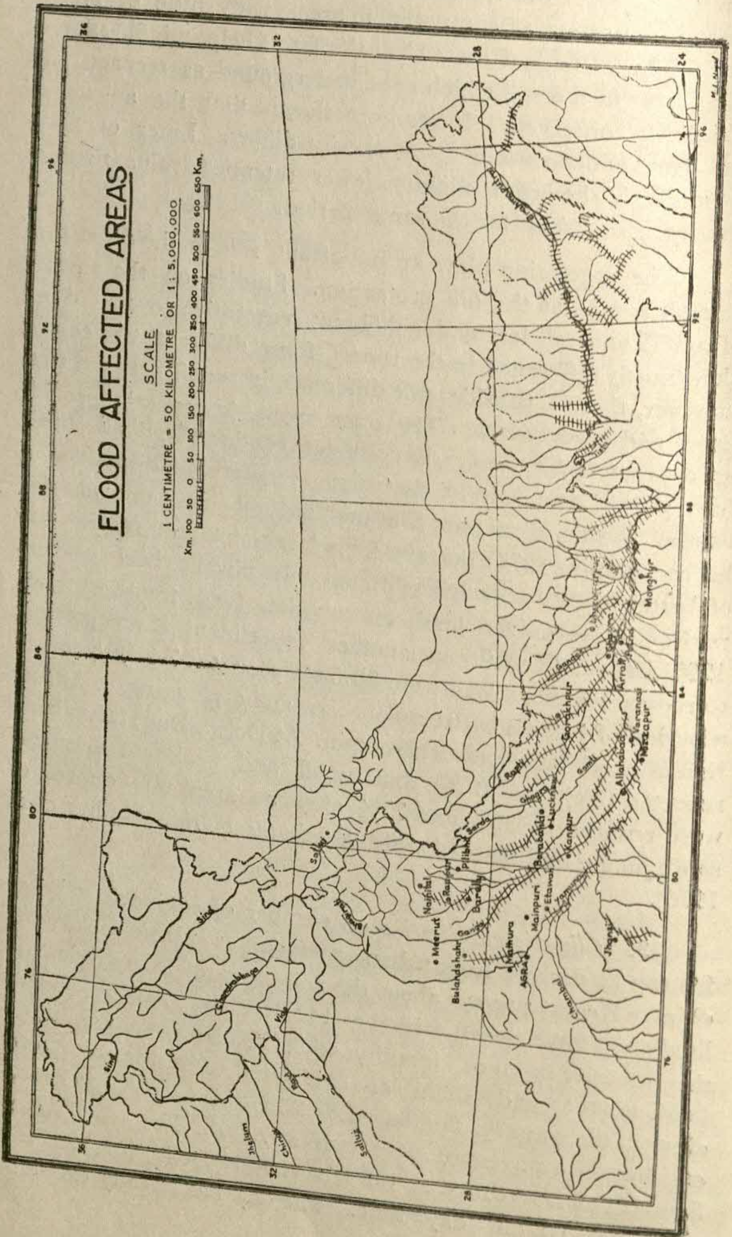
in the country, they suggest particular periods of history like some of gardens created by Moghuls. In all cultures, plants form a part of the human environment (Randhawa, M.S., 1950). Jackson (1951) recalls typical arrangement of grassy lawn with shade trees as the appropriate setting for cultured life. Without vegetation, cities would lack green forms, reminders of the changing season which contrast sharply with the buildings and help to increase pleasurable complexity in a sensually impoverished milieu.

2. *Check soil erosion and reduce floods*—Trees and shrubs alongwith their ground-cover help in checking the soil particles from being washed with the rains and thus help in checking floods and silting of reservoirs. The rainfall disposal is modified through interception of the rainwater through their canopy cover, proper infiltration through the forest litter and modification of soil and runoff losses. Studies on the rate of sedimentation in 17 major reservoirs constructed during the 3rd & 4th Five Year Plans in the country, have revealed that as against the average rate of the designed sediment inflow of 2.93, these reservoirs are receiving an average sediment inflow of 9.17 mh/100 km^2/year which is 213% more than the designed rate (Anonymous, 1974). It has been estimated that the total annual loss of soil nutrients which take place through loss of fertile top soil is of the order of 5.37 m tonnes of NPK and is of the value of Rs. 700 crores. The amount of soil displaced is of the order of 60,000 m tonnes, a part of which finds its way to the sea. A good deal of this sediment gets into irrigation tanks, reservoirs and riverbeds. Seasonal floods are estimated to have caused an annual loss of Rs. 300 crores by way of damage to crops, animals, habitations and public works. Floods in Bihar alone have, caused an estimated loss of Rs. 180 crores in a year (Vohra 1974).

The infiltration rate of water in the soil has been shown to be lowest under the agricultural land and highest under the woodland. Shola forests of Nilgiris, Broom and Bluegum plantations in the same region had much higher infiltration rates than grazed grasslands. Under different forest conditions, the infiltration rates vary considerably depending upon the condition of the forest floor viz. Sal forest with good leaf litter show higher rate of infiltration as compared to areas with little or no leaf litter. Thus, the leaf litter from the forest help in infiltration of rain water in the soil which goes underground as seepage and ultimately conserved. It has been shown that the amount of leaf litter under various forest species differs. Litter of *Eucalyptus hybrid* showed a slightly lower retention value than of *Eucalyptus citriodora* for the same period.

The vegetation plays an important role in the disposal of rainfall as well as the soil protection. Studies on the amount of runoff and soil loss under different vegetative covers did not show much difference in the runoff from different tree covers; however, there is considerable difference in runoff between tree, shrub and grass covers. The grass covers, in general, provide good protection to soil. Experiments conducted all over India have proved conclusively that trees regulate the disposition of rainfall in such a manner that man not only get more waterfor his use (Gupta, 1974) but also for a longer time in a regular way of better quality with less sediment. In Siwalik hills, in comparison to overgrazed land, afforestation (with trenches) gave 129% less runoff while in another experiment it was possible to reduce sediment load from 80.5 t/h/year to 7.4 t/h/year, in a period of 4 years by tree planting, gully plugging, construction of check dam and debris basin. At Dehra Dun, it has been reported (Tejwani, 1976) that runoff and peak rate of runoff were reduced by 33% and 77% after an area was cleared of scrub jungle and planted with *Eucalyptus hybrid* (Mathur et al 1976).

3. *Climatic amelioration*--A number of engineering benefits can be derived from urban vegetation as planned fabric of cities. Recent surveys about the noise level of many industrialised cities have shown a level of 140 decibels. A noise level of this intensity produce insanity while 120 DB is the pain threshold. Bombay and Delhi are considered to be the most noisy cities in the country. Bombay with 2.25 lakh houses, trucks and cars has on an average noise level of 75 DB. The noise level at Santa Cruz is recorded at 105 DB while in Delhi, it is recorded as 50-120 DB in day time. The city has already exceeded


FLOOD AFFECTED AREAS
SCALE
1 CENTIMETRE = 50 KILOMETRE OR 1 : 5,000,000
Km. 100 50 0 50 100 150 200 250 300 350 400 450 500 550 600 650 Km.
36
32
28
24
76
80
84
88
92
96
Jhelum
Chinab
Ravi
Satluj
Sind
Chandrabhaga
Vias
Satluj
Meerut
Bulandshahr
Mathura
AGRA
Mainpuri
Etawah
Yamuna
Chambal
Jhansi
Naini Tal
Rampur
Bareilly
Pilibhit
Sarda
Ganga
Barabanki
Lucknow
Kanpur
Ghagra
Rapti
Gorakhpur
Gomti
Allahabad
Mirzapur
Varanasi
Arrah
Patna
Gandak
Monghyr
Brahmaputra

the 80 DB limit which one can tolerate without slow damage to one's power of hearing. Recent study by researchers, engineers, medicalmen, psychologists and urban system planners, show that high level of noise adversely effects public health and people living in cities become victims of cardiovascular, respiratory and neurological diseases. Noise produces temporary constriction of the smaller arteries, speeding up pulse and respiratory rates, while steady exposure to loud noise result in diziness, headaches, fatigue, inefficiency at work, rise in blood pressure, tense muscle hypertension, abnormal heart rhythms and even ulcers. Physiological research on human beings has shown that even short-term exposure to noise at 150 DB leads to contraction of blood circulation, body exhausion and nervousness, dialatoriness in the eyes, stomach and intestines. What is worse, these troubles are not always curable.

Notice may be taken of the potential role of vegetation in noise reduction, in environmental monitoring and in climatic amelioration of the human habitat. Smith (1970) concluded that significant noise reduction through use of vegetation might require buffer strips of plants 130 m or more. Cook and Van Haverbecke (1971) measured loudiness behind shelterbelts containing various tree and shrub species. Acoustical effects of several kind of surface and vegetation show variation with frequency of sound and distance to receiver (Ayler, 1971 a, b, c,). Nevertheless, general conclusions indicate a major potential for reduction of noise intensity by relatively narrow strips of plant material in urban areas.

4. *Air pollution and heatwater balance*—Almost no city in the country can be said to be free of one kind of pollution or another. Delhi is known for its winter smog, Bombay for its noise menace and Calcutta for its foul air chocked with smokes from its several chimney stacks. Urban society produce air borne waste in concentrations greater than the plants can survive and a number of technological changes are made (Bach 1972 a). Sulphur gas from the railways and power generation plants have shown undesirable effects on famous

Red Fort of Delhi. Sulphur di-oxide concentration in the atmosphere in Delhi has been recorded at 0.233 ppm.

Chakraborty & Rao (1962) carried out a 3 year Survey of air pollution in Calcutta. The results are given in table below :

Table 1—**Atmospheric pollutants in Calcutta**

Atmospheric pollutants	*Ramge*
Sootfall	39.98-90.98 t/sq mile/month.
Sulphur-di-oxide	0.021-0.058 ppm.
Oxides of Nitrogen	0.043-0.122 ppm.
Ammonia	0.160-0.266 ppm.
Aldehydes	0.04 to 0.12 ppm.
Respirable dust	0.071-0.600 mg/cu m of air.

In 1968-69, Environmental Engineering Research Institute, Nagpur (Yannawar, et al. 1976) carried out air quality surveys in Bombay, Delhi, Calcutta and Kanpur. The survey revealed existence of high-pollution levels at certain places in cities. The dust concentration in these cities is shown in the table below :

Table 2—**Suspended particulate matter**

City	*Suspended matter* ug/m
Bombay	238
Calcutta	527
Delhi	700
Kanpur	488
London	221
New York	134

Adverse effects of Mathura oil refinery on Taj and other historical monuments in Agra region have been brought out in press reports. The expert committee on Environmental Impact has recommended closure of two coal based power plants to achieve significant reduction in the existing level of SO_2 in the atmosphere in addition to relocation of existing small scale industries such as foundaries, replacement of coal fired locomotives by diesel locomotives and by relocating large industries such as fertiliser and petro-chemicals.

Studies by the Indian Meteorological Department and National Environmental Engineering Research Institute have shown that the refinery's contribution to long-term Sulphur-di-oxide concentration at Agra would be 1-2 microgroms per cubic metre as compared to existing level of 15-20 micrograms. Short term (one hour) peak concentration of 65 micrograms per cubic metre is expected under the worst meteorological conditions in winter. Frequency of such occurrences will be 2-4 per cent for Agra region and zero to 1 per cent for the Bharatpur region. The Sulphur-di-oxide concentration in micrograms per cubic metre in some major cities of the world is : London city 250, Milan 600, Brussels 170, Paris 110, New York 110, Los Angeles 70 and Toronto city 170. It is expected that the actual long term refinery contribution to Sulphur-di-oxide levels at Agra shall be 2 micrograms per cubic metre. Large-scale plantation programme in the region would be helpful to keep this within safe limits.

Similarly, salt-laden winds from sea have adversely affected some of the famous temples at Konarak. It Calcutta City alone, particulate concentration in atmosphere is very high by emission from industries, automobiles and domestic sources. City atmosphere receives over 632 tonnes of "pollutants" every day. The concentration of contaminants has reached nearly 10 per cent of the maximum permissible limit. A recent Seminar on National Capital Region (NCR) indicated that in Delhi alone 30 tonnes of hydrocarbons, 240 tonnes of Carbon-mono-oxide, 2 tonnes of Sulphur di-oxide and about 20 tonnes of Nitrogen oxides are discharged every day from Motor vehicles. Thermal power stations of Delhi dump about 60 tonnes of flyash and 70 tonnes of SO_2 per day in addition to 400 kg of toxic material like arsenic, vanadium and fluorides. Carbon mono-oxide concentration from auto-exhaust (Petrol driven) is about 10-35 ppm. The country experienced an increase of Carbon-di-oxide content in the air by 13 per cent during the last century and it is expected that there will be another 20 per cent rise by the end of next century, The residual quantity of pollutants which are difficult to capture except at enormous expense remain in urban atmosphere. For them vegetation can act as important link (Hill, 1971). A rough quantitative example of the role of plants in absorbing Carbon di-oxide has been given by Lanphear (1971). In addition to active uptake of gases into leaves via stomata, leaf surface provide vast area of setting of particulates and absorption of further gaseous wastes. Decrease in atmospheric turbidity has been recorded by the vegetation (Bach, 1971; Neuberger *et al.* 1967). Plants are recorded not only to release pollen into the atmosphere but also reactive hydrocarbons (Resmussen, 1972); thus, contributing to, as well as reducing, the burden of atmospheric contaminants. Fortunately, volatile terpenes are perceived by people as fresh air rather than dirty air.

5. *Moderate effect of wind and incoming radiation*—Individual homeowner would like the vegetation to provide maximum effect on wind and incoming radiation. Landscape architects for at least a century have given advises to urbanites, though the use of shelterbelts and trees is well understood from a technical view point, it is rarely applied in contemporary cities.

Due to rapid industrialisation, radiation balance and atmospheric turbidity over the past 15 years has shown an increase of the later and the decrease in the incoming solar radiation in Calcutta, New Delhi and Poona. In Poona city alone, turbidity increased by 100% and solar radiation decreased by 10% since 1960. Concentration of dust in the atmosphere in Calcutta, Delhi and Bombay today is 2.5 times higher than in many cities in the west.

Oke (1972) calculates that two third of the total potential evapo-transpiration from a completely vegetated surface can occur if plants cover about one third of the city's land area. This evapo-transpiration becomes significant in terms of human health during heatwaves when a few degrees difference in temperature can sharply influence heat prostration (Clarke, 1970). It has been recorded (Federer 1971) that a single isolated tree by evaporating 100 gallons of water per day accounts for

2,30,000 K cal of energy, the equivalent of cooling of five average room air-conditions (each 2500 K cal/hour) running 24 hrs a day. The air-conditioners, however, merely shift heat from indoors to outdoors and they do not operate with perfect efficiency which vary from brand to brand. They ordinarily release heat elsewhere in urban area. How the meso-climatic effects of individual trees are to be aggregated is yet unknown since two trees do not transpire twice as much as one if they are competing for limited moisture.

6. *Promote mutual understanding and co-operation*—Exchange of plants at national and international level promote mutual understanding and regional co-operation. Emperor Ashok sent missionaries and planted trees. Visiting dignitaries plant trees as a mark for mutual understanding and co-operation. Through various functions for soil conservation, flood reduction and man's dependance on traditional uses of forests, they promote human welfare. These provide shelter and shade, fuel, timber, forage and fodder, fibre, paper, medicine and scenic beauty.

7. *Economic return*—Vegetation could be managed for economic return. Many European cities have long found timber production within city limits a profitable enterprise. Thus, almost one quarter of Zurich is forested (Holscher 1971). There is a great possibility of exploiting city vegetation by municipalities and local bodies, Public Works Department and Forest Department—trees and shrubs for fuel which is a major source of domestic fuel requirement in the country.

Back to firewood—The dwindling reserves of Oil and Natural Gas have again focussed attention on alternate sources of energy. Some analysts look to the development of a single 'ideal' form of energy that will rapidly take-over and reign in perpetuity. Firewood is still the primary source of energy for more than one third of the world's people. Erik P. Eckholm in his report "The other energy crises firewood" noted that for many people, the real energy crises is the daily scramble to find the wood they need to cook dinner. It has been expressed that by the end of the century, we may have the food but not the fuel to cook it. The firewood crises is forcing a basic reanalysis of man's relationship with land. The establishment of forest farms and other social forestry practices could supply a substantial requirement of firewood and such a source of energy would be self renewing.

On a rough estimate, 86,000 thermal units are required to cook the food of a family of 5 persons (Pal, 1955). However, considerable quantity is wasted in indigenous oven using firewood. The loss is estimated at 15,000 thermal units tentatively so that for effective cooking, 1,00,000 thermal units per day are required. This heat is available from 5.45 kg of firewood and 3.63 kg of cowdung cake. An average cattle is supposed to yield about 5 tonnes of dung per year. About 60 mt of dried cowdung cakes are estimated to be burnt as fuel with corresponding loss of manure to the soil (1% N). Though the farmer is aware of the need for fuel and fodder slow growing species provide 75% of fuel sold in the market. It is, therefore, desired that fast growing species on short-rotation be planted in woodlots under this programme to meet immediate requirements. Calorific value of some of the indigenous species is *Calligonum polygonoides* 7590 BTU/lb, *Prosopis cineraria* 7640 BTU/lb, *P. juliflora* 8050 BTU/lb, *Salvadora oleoides* 6770 BTU/lb, *Capparis decidua* 8050 BTU/lb and *Acacia tortilis* 7800 BTU/lb.

The role of exotics—Among the exotic species, *Eucalyptus* sp., *Acacia tortilis* and *Prosopvs juliflora* are the most important, which deserve any mention. Though the first introduction of *Eucalyptus* in India dates back to 1843, regular plantation work commenced in 1856. *E. globulus* was perhaps the first which was not only successfully grown but fulfilled the objectives of management. Subsequently, as many as 30 species were tried in the twenties of the peresent century. Kaul and Nambiar (1966, *Indian Farming*) suggested a number of promising species, viz. *E. camaldulensis*, *E. melanophoia*, *E. coolabah*, *E. oleoosa*, *E. ochrophloia*, *E. salmonophloia*, *E. stricklandi*, *E. terminalis*, *E. tesselaris*. Adaptability trials of 43 species at Pali and Jodhpur showed (Kaul, R.N. *et al*, 1969, *Qualitas* 27: 131-147) that only species with wide latitudinal distribution and belonging to summer rainfall regions in the native habitat have done well as compared to species with narrow latitudinal distribution and belonging to winter rainfall areas. In general, *E. melanophoia, E. terminalis, E. camaldulensis* are most promising for conditions of Jodhpur while for Pali having calcareous soils, *E. tesselaris* is promising. Though the plant can survive by watering in areas with rainfall of 25 cm or less, it suffers badly during the hot summer seasons and the maximum mortality occurs at that time. Roots form a net work just below the soil surface to extract every bit of moisture. This results in poor undergrowth. Though it has been recorded that it can be grown under a range of conditions from semi-arid to waterlogged, canal irrigated and mildly saline soils, it would be better no longer to hope or attempt if any of the *Eucalyptus* would grow to the extent of giving economic returns over our indigenous species in regions of rainfall less than 25 cm. Considerable scope is afforded under rainfall regions of 50-100 cm. Though in Australia, it has innumerable uses such as building railway carriage, poles, etc., in India for commercial value, it is still considered inferior to indigenous species, the timber being light. It is, however, being extensively utilised for roadside plantations in Haryana and Punjab and for utilisation and reclamation of waterlogged areas. Few recommended species are—

Under irrigated conditions : *E. hemiphloea, E. melanophloia*
Semi-warerlogged conditions : *E. botryoides, E. gomopholea, E. grandis, E. robusta, E. camaldulensis, E. occidentalis, E. hemiphloea, E. redema, E. siderophloea, E. tereticornis.*
Oreamental : *E. ficifolia, E. caesia, E. calophylla, E. macrocarpa, E. cosmophylla.*

Plantations of *Eucalyptus hybrid* at a distance of 2.5 m apart on field bunds in Saharanpur district gave a total income of Rs. 900/- per hectare. The average height at the end of 7 years being 11.2 m and 40 cm DBH (Singh and Srivastava, 1973, *Soil Cons. Digest*). In addition to *Eucalyptus*, Bhabhar was planted at a distance of 25 cm in 4 rows over the bund and was sold at Rs. 300/- at the end of 7 years.

The belief that *Eucalyptus* causes drying of sub-soil and causes the water table to recede is gaining ground. Perhaps this conception is based on the fact that certain species of *Eucalyptus* planted in the Pontine marshes near Rome reclaimed these marshes. Similarly, certain species of *Eucalyptus* when planted on roadsides, dried up burrow pits common on both sides of the roads in the country. Studies conducted at the Forest Research Institute & Colleges, Dehra Dun have shown that the water consumed per gm of dry matter produced is least for *Eucalyptus* (1.41 mm) as against rosewood (2.59mm) and chir (8.87 mm). Studies on evapotranspiration from *Eucalyptus* have shown in Israel that evapotranspiration from *Eucalyptus camaldulensis* is low and slightly higher than bare land. Studies on interception of rainfall by a few year old E. *camaldulensis* plantation indicated about 14-15% of total rainfall lost as interception. Similar experiments conducted at other places have shown that with *Eucalyptus*, no transport of sediments was observed over a number of years. (Mathur *et al* Indian for 1976. 102 : 219-226). At Ootacamund, similar studies (Thomas *et al.*, 1972) have shown annual transpiration loss to rain-fall in *E. globulus* plantations as only 1:235 which does not seem to much adversely effect the water yield in the existing reservoirs.

Prosopis juliflora called the Royal plant has the capacity to establish under varied habitats. The tree in areas above 20 cm of rainfall have prolific growth but the plant do not tolerate excessive drought and frost. Growth on hard claypan is slow, though on account of its resistance to salts, it establishes on saline conditions. It has been recorded to inhibit the germination of a number of species (Gaur and Lahiri, 1969, *Proc. Nat. Inst. Sc.*, Chatterji and Mohnot 1968, *Recent adv. in trop. ecol.*). Stump planting is generally practiced where direct sowing or entire transplantation do not succeed. Presprouted stumps of this species of 1.5 cm collar diameter and 17.5 cm root length is recorded by Bhimaya *et al.* (*Ann. Arid Zone* 1965) as the most suitable size for presprouting them in nursery. The field establishment and subsequent growth in height remains unaffected by these sizes. The DBH and tree height are positively co-related with the fuel yield which accounted for 42.58 and 24.76 per cent of the total variation as shown by Bhimaya *et al.* 1967 (*Indian For.* 93: 355-359). For predicting fuel yield DBH alone is sufficient (Kaul and Jain, 1966, Kaul et al. 1964). The equation y = 2.10 + 5.0.8x where y is the yield in kg and x the DBH is used for prediction. With a unit increase in DBH fuel yield is recorded to increase by 5 kg.

Comparative study on the germination of *Acacia tortilis* and *Prosopis juliflora*, the two promising exotics, have shown (Gupta and Balara 1972, Indian For. 98: 280-285) that *Prosopis juliflora* till the 4th week of its establishment as regards its root and shoot length is a better species than *Acacia tortilis.* After which *A. tortilis* takes an edge over *P. juliflora* because of higher dry matter from shoots, nodule formation, better photosynthetic ability due to large leaf numbers and higher secondary rootlets. Like *Prosopis* it coppices well and is relatively better resistant to frost and drought conditions.

Tropical Pines—These have been recently introduced in the country. Preliminary trials have proved to be encouraging. The following species have been recommended for various parts of the country. These are fast growing as compared to our indigenous pines like *Pinus roxburghii* of the Western Himalaya.

Andhra Pradesh — *Pinus caribaea, P. khasia.*
Himachal Pradesh — *P. patula, P. massoniana.*
Kerala — *P. caribaea, P. elliotti.*
Orissa — *P. caribaea, P. Khasia.*
Tamil Nadu — *P. patula, P. elliotti.*
Uttar Pradesh — *P. patula* in hills, *P. caribaea.*
W. peninsula — *P. patula* in hills.

Poplars—Though primarily a farm species, these can grow both inside and outside the forest. The fast rate of growth and advantage of growing agriculture crop as intercrop, makes it an ideal plant. Some of the common species recorded within the country are—*Populus nigra, P. alba* primarily in Kashmir hills, *P. deltoidea* is recommended for hills of Uttar Pradesh, *P. ciliata, P. gamblei* are the indigenous species later being confined only to Eastern hill regions of Bhutan and Arunachal Pradesh.

Some of the other species which have been adopted for large scale cultivation are i) *Cryptomeria japonica* in Eastern Himalaya (1850-2150 m) is grown on a large scale and is estimated to produce 740 m^2 pulpwood/ha on 30 years rotation and total production on 60 years at final felling is 1285 m^3/ha of which 55% is small wood; ii) *Cupressus cashmiriana* in Kalimpong hills (1550-2180 m) is recorded to gives 750 m^2 pulpwood/ha at 30 years rotation.

Physiographic and Ecological Diversity in India

India can best be divided into 5 physiographic regions :

1) *The Great Mountain Wall* : It varies enormously from end to end in climatic conditions. Elevation and spacings of ranges play an important part in the differentiation of the mountain ranges into distinct regions.

A) *Western Himalayas* : Include J & K, H.P. and hills of U.P. Massive build of Kashmir distinguishes it from Punjab and Kinnaur Himalaya of Himachal and U.P. which show less complexity of structure.

B) *Eastern Himalayas* : For some 224 km it passes through Sikkim and 640 km through Bhutan. NEFA with forest hill lie in this tract. Excluding Bhutan, eastern hills may be differentiated into i) Darjeeling-Sikkim Himalayas; and ii) Assam Himalayas and Eastern Border hills and Plateau.

2) *The Great Northern Plain* : This is the largest and most densely populated alluvial plain in the world. It is a great lowland plain covering nearly 1/5th of the total area of India. It is filled-up with deteritus brought by rivers from the Himalayas and peninsular plateau. The rivers meandering over this plain, may be grouped as Sutlej-Beas system, Ganga-Yamuna-Sarda system, Gandak-Kosi and Brahamputra systems. The regional differences in topographic details are slight but climatic variations are marked. Sub-divisions of this plain, according to climatic variation are : i) North-West plain (driest); ii) Upper Ganga plain; iii) Middle Ganga plain; iv) Delta plain; and v) Brahamputra valley.

3) *The Central Indian Highlands* : It has two physiographic units namely North-West peninsular plateau and North-East peninsular plateau.

A. *North-West Peninsular Plateau* : It is a wide belt, hilly country bordered on West by Aravalli ridge, on South by

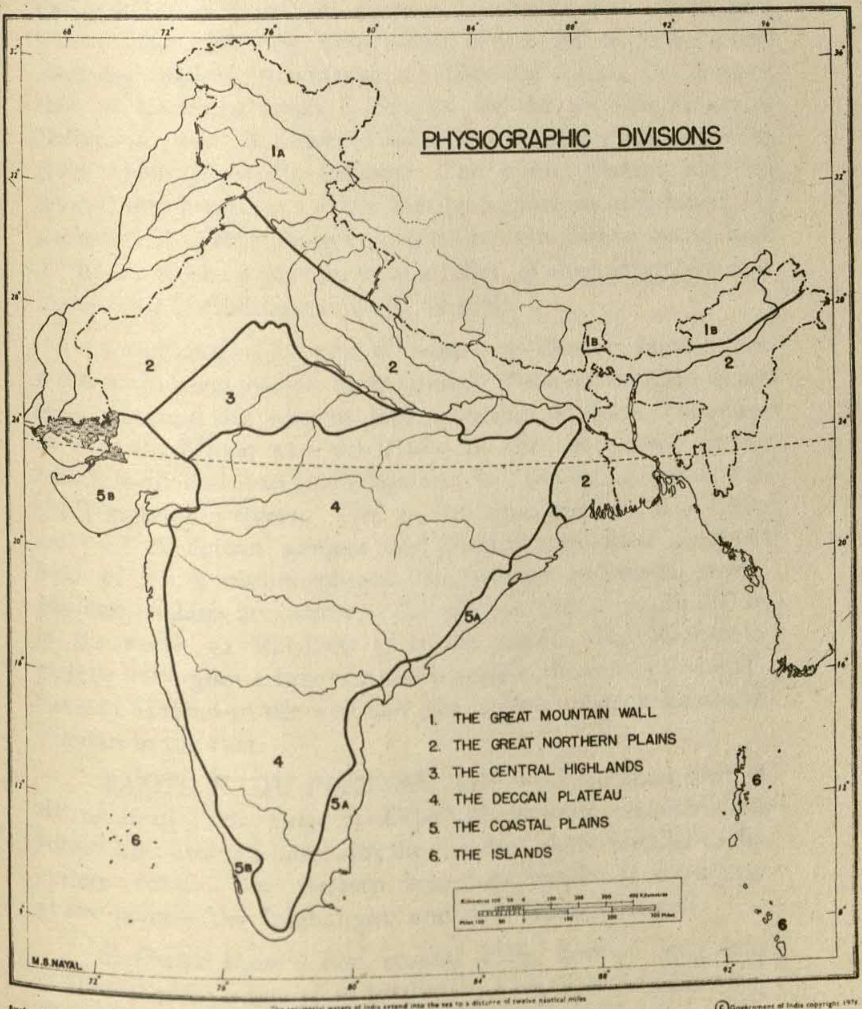
Vindhyan scarplands and Vindhyan ranges and on North, by peninsular edge of Indo-Ganga trough. It covers about 1/4th of total area of peninsular plateau. It may be further sub-divided into following sub-regions : i) the Aravalli ranges; ii) Chambal basin; iii) Bundelkhand uplands; iv) Malwa plateau and v) Vindhyan scarplands.

B. *North-Eastern Peninsular Plateau* : This is a single entity with following characteristics : i) the entire area is more than 150 m alt. and eastern states form the boundary in the East; ii) the plateau is formed essentially by a great complex of precambrian rocks, though in some areas, masked by alluvium and older sediments; iii) the rainfall everywhere exceeds 1600 mm. Its northern boundary follows the northern rim of Baghalkhand and Hazaribagh plateau terminating at Rajmahal hills; its western boundary follows the edge of Maikal range; its southern boundary follows the rim of Bastar plateau and its eastern boundary is set by the edge of Eastern Ghats and Chota Nagpur plateau.

4) *Deccan* : In the Deccan, has been included all that tract of land between the Central hills and plateau above and the western and eastern coastal plains encircling it below. The Deccan has been divided into four sub-regions corresponding to political territories, viz. Maharashtra Deccan, Andhra Deccan, Mysore Deccan and Tamil Nadu plateau.

The Maharashtra Deccan is a region of extraordinary physical homogeneity because of its characteristic lava rock. It has three physiographic regions : i) the Lava ghats; ii) the Lava plateau rimmed in the north by Satpura range and in the north-east by Maikal range terminating in the east and south where the Archaean gneisses dominate the landscape and the iii) Wainganga valley immediately to the east of Nagpur basin.

The Andhra Deccan with its bordering eastern states, is carved out of the Archaean gneisses. To the north-east of the plateau, there is a chain of hills which widen to the north of Godavari and reach an elevation of 900-1500 m. The rampart of the eastern hill is completely breached for 1600 km between Godavari and Krishna. To the south of Krishna lies



Based upon Survey of India map with the permission of the Surveyor General of India.

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

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the range of Cuddapah hills forming a crescent, the heart of it being the wide Nandyal valley drained by the Kundura river, a tributary of river Pennar. In the west, this trough is marked off from the Deccan plateau by the scarp of Seshachalam and Palkonda hills formed of massive quartzites with slates and lavas. The Palkonda hills rising above 900 m form a fine scarp over looking Anantapur and Chittoor basins. The eastern limb of Kundura basin is formed by the parallel ranges of Nallamalai and Velekonda hills, separated by the Segileru river which joins the Pennar. The entire plateau may be divided into two units : i) the Telengana plateau developed on gneisses with a fault trough occupied by Gondwana rocks and ii) the Rayalseema plateau with a relief of alternating hills and basins built of Cuddapah system of rocks.

Karnataka region extends from the Deccan lavas in the north to the river Moyar in the south. Its western limit is the ghat crest and its eastern limit provides a sharp boundary between the Moyar and the Palar in the south-east. In the east, it is divided into basins drained by Bhima, Krishna and the Tungbhadra rivers. The entire area consists of a basement of Archaean gneissis and granites intersected by great belts of much mtamorphosed Dharwarian sediments mostly phyllites, schists and slates. The plateau rises from 450-750 m in the north to 900-1200 m in the south. The Karnataka plateau undergoes a fundamental diversion between the highly forested Malnad in the west and the rolling plateau known as Maidan in the east.

TAMIL NADU PLATEAU is the southern most part of the peninsula, triangular in shape with its apex coinciding the Nilgiri hills and the base with the eastern ghats parallel to the eastern coast. The western boundary breaks its continuity at two points—the Palghat gap and the Shencottah gap.

5) *Coastal plains* : The coastal plain forms a long strip of alluvial plain hammed in between the sea and the ghat area. The coast on the west is narrow and the ghats rise steeply from the plain. In the east, it is wider at points where the rivers have formed deltas and the ghat behind it is neither a countinuous range nor very high in altitude. The west coast is obvi-

ously better than east coast because it is directly exposed to the south-west monsoon currents. The entire west coast except that falling in Gujarat state enjoys average rainfall of more than 2000 mm. The east coast on the other hand, is drier because of its leeward location and gets exposed more to retreating than to the advancing monsoon. It gets rainfall twice a year, though its annual rainfall exceeds 1000 mm.

The west coast is a coast with creeks and well-defined routes to the interior and has 5 major regions, viz. the Kutch peninsula; ii) the Kathiawar peninsula; iii) Gujarat plains; iv) Concan coast and v) Carnatic and Malabar coast.

The east coast form strong contrast to the west coast in topography. The coastal plain in the coast is much wide and most to it is formed of the great deltas of Mahanadi, Krishna and Cauvery. It may be divided into three sub-limits : i) Tamil Nadu coast; ii) Andhra coast; and iii) Orissa coast.

In addition, we have islands viz. i) the Laccadiv, Minicoy and Amindiv Islands; ii) the Andaman and Nicobar islands.

The Laccadiv, Minicoy and Amindiv islands located about 240-480 km from Malabar coast owe their origin to the accumulation of coral detritus on the submarine swell. These are all small islands fringed with Coconut palm groves.

The Andaman islands lie in Bay of Bengal about 944 km from the mouth of Hooghly and consists of a mass of hills enclosing very narrow valleys and whole area is covered by a dense tropical forest. The hills rise to a considerable elevation especially in the east coast.

The Nicobar group of islands cover an aggregate area of 13,456 sq km with physiographic diversity. Thus from north to south, Car Nicobar is a coral covered island and Chowra is a flat hill at the south and the Little Nicobar is mountainous. Car Nicobar, though tropical in appearance, shows a continuous fringe of Coconut palms.

Ecological Subdivisions :

Among the major ecological parameters required for good growth and development of tree plantation in the country are rainfall distribution, temperature-maximum and minimum of the hottest and coldest months respectively, soil conditions and their effective protection. Since major proportion of the annual precipitation in the country falls in the form of rains during the rainy season (s), this is perhaps the best period for the tree planting programme. The temperate situations are perhaps the exception, the temperate frost resistant species are planted when they are dormant such as *Salix*, *Juglans regia*, *Pyrus sp.*, *Prunus* sp., etc. As far as the soils are concerned, the main hazard apart from the texture and structure is the presence of salts and/or the presence of impermeable kankar zone which hampers the root development. Such a situation is commonly met on the old alluvium flats in North-West India. The Calcium Carbonate nodules occur at varying depths. Though initially the plants show very good growth for a few years, gradually they start drying and sometimes show pollarded growth. Examples of such situations were observed at Jodhpur where plants of *Delonix regia*, *Jacaranda mimosaefolia* and *Dalbergia sissoo* failed finally though showed encouraging results in the initial years of establishment. Based on soil and climatic data, the country has been broadly divided into the following 8 ecological zones*

1. Humid Western Himalaya — J&K, H.P., Kumaon Garhwal.
2. Humid Bengal Assam — West Bengal & Assam.
3. Humid and Himalayan region and Bay Islands — Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Sikkim, Meghalaya, Andaman & Nicobar Islands.

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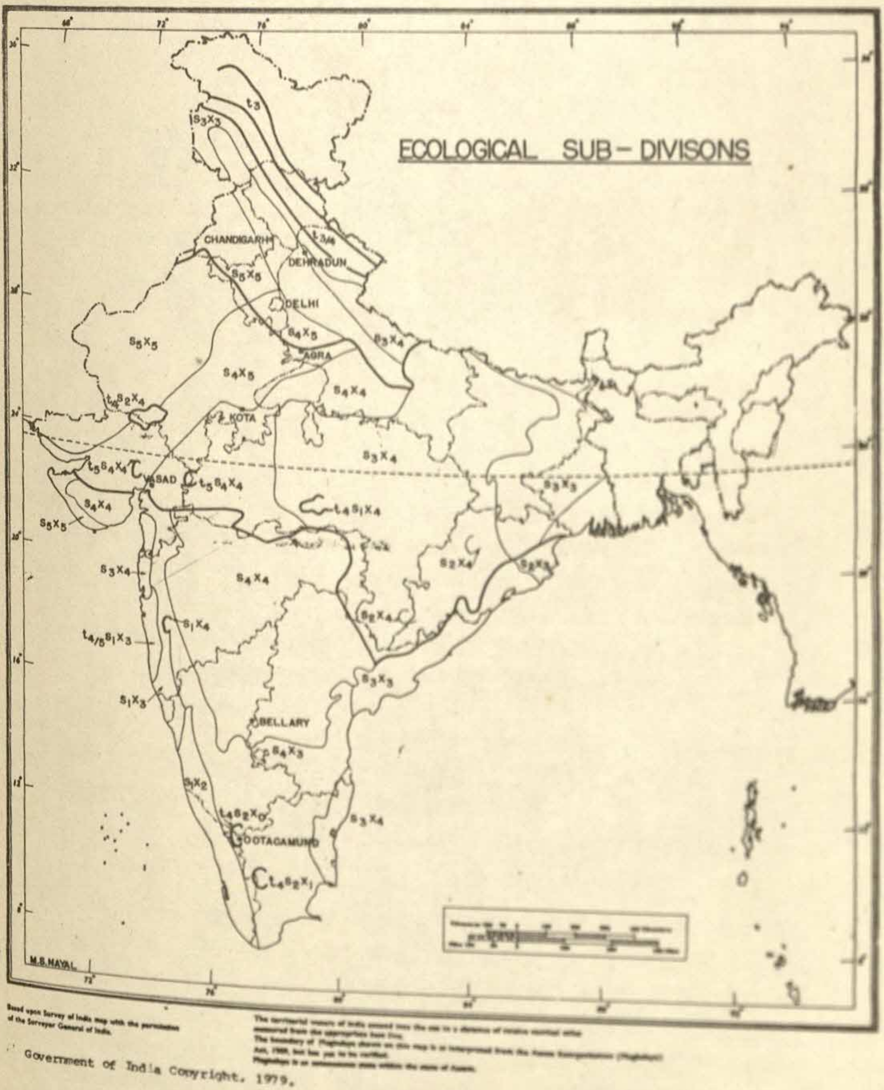
*The major ecological regions are based on the map published in DARE report for 1977.

4. Sub-humid Sutlej-Ganga basin — Punjab, Delhi, U. P. plains and Bihar.
5. Sub-Humid to humid-eastern and South-Eastern upland — East M.P. (Balaghat, Mandra, Shahdol, Sidh, Surguja & Bastar), Orissa and Andhra Pradesh.
6. Arid Western Plain — Haryana, Rajasthan, Gujarat, Dadar and Nagar Haveli.
7. Semi-arid Lava plateau and Central Highland — Maharashtra, Western & Central M.P., Union territory of Goa, Daman and Dieu.
8. Humid to semi-arid Western Ghats and Karnataka plateau — Karnataka, Tamil Nadu, Kerala, Pondicherry and Lakshdeep Islands.

I. *Humid Western Himalaya*—It comprises of Jammu & Kashmir, Himachal Pradesh, Garhwal and Kumaon regions of Uttar Pradesh. The area presents varying altitudes which could be divided topographically into inner, middle and outer hill ranges comprising of the valleys. The lands are undulating and are subjected to heavy soil erosion and runoff from the sloping hills. The area receives sufficient rain-fall, primarily the outer and midddle ranges, while the inner hills get snow. This makes possible raising of two crops in a year. Pattern of rainfall is somewhat different in Kashmir valley showing a tendency to mediterranean type while the hills of Jammu, Himachal Pradesh and Uttar Pradesh expereince typical monsoonic type of climate. However, the factor of non-uniform and erratic distribution of rainfall present problems of moisture deficiency and excess.

Wheat, Paddy, Maize and Potato are the main crops of the region in addition to coarse millets like Jhingora, Mandua, Cheena, Marsa, Oogal which are cultivated on a small scale. Due to the ever-increasing demand on land, the natural vegetation is being cleared. The community lands being everybody's property are no man's responsibility and thus are in



Based upon Survey of India map with the permission of the Surveyor General of India.

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the Assam Reorganisation (Meghalaya) Act, 1969, but has yet to be verified.
Meghalaya is an autonomous state within the state of Assam.

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bad condition. These lands provide potential site for planting programme in addition to roadsides and farmers field where terrace risers are put under some tree and shrub vegetation used for leaf fodder, fibre and fuel. Even the reserved forests are revegetated with fast growing, economically important species at the cost of indigenous plants like Oaks which are supposed to have a better conservation value. Though there is an urgent need to develop suitable cropping patterns for hill situations such as outer, middle and inner hills and valleys, plantation of trees and shrubs for sylvo-pastoral management, horticultural development need special attention.

II. *Humid Bengal Assam region*—This region comprises the State of W. Bengal and Assam. The soils are primarily derived form deposition laid by numerous tributaries of Ganga and Brahamputra systems. The rainfall is sufficient during the monsoon season but there is lack of soil moisture during winter and summer months. Jhum cultivation on the hill slopes, torrent bank erosion, gully erosion in the plains and afforestation of grazing reserves are the major problems of soil conservation. Common species recommended by the State Soil Conservation Departments are *Pinus insularis*, *Albizia lebbeck* *Dalbergia sissoo* and *Schima waliichii* along with some other specees like *Toona ciliata*, *Shorea*, *robusta* and *Tectona grandis*.

III. *Humid Eastern Himalayan region*—This zone comprises of Arunachal, Nagaland, Manipur, Mizoram, Tripura, Sikkim, Meghalaya, Andaman & Nicobar Islands. The high rainfall and humid areas receive high monsoon rainfall and are subjected frequently to floods during the rainy season but experience drought in summer and winters. Annual crops like rice and plantation crops like tea, coffee have been found to be the choice in many of the areas depending on topography, soil, and climatic conditions. The heavy monsoons coupled with the undulating topography pose several serious problems such as loss of soil fertility by heavy leaching, soil erosion, phosphatic fixation and deficiency of micro-nutrients. The annual crops are prone to flood damage. The practice of shifting cultivation which is in vogue, pose many problems. Road construction works, both for defence and

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development and resettlement programme in many of the areas pose serious problems of land management and soil erosion. Therefore, it is imperative that spoiled and delapidated habitats and torrent beds be rehabilitated with productive vegetation cover. The area could provide suitable habitat for several plantation crops, orchards, and sylvo-pastoral practices in addition to fuel and production forestry practices for timber and other woods with proper management.

IV. *Sub-humid Sutlej-Ganga basin*—It is by far the most important and the largest region of the country contributing largest share to agricultural wealth to the country. It comprises of the States of Punjab, Delhi, Haryana and plains of U.P. and Bihar. The main features of the soils are derived from the deposition, the silt laid by numerous tributaries of the Ganga and Yamuna river systems. The streams draining the North-Western Himalaya bring with them the product of weathering of the rocks constituting the mountains in various degrees of fineness and deposit them as they traverse the plains.

The region receives sufficient to heavy rainfall during the monsoon season but sometimes there is scarcity for water during summer season. However, the underground water resources are good and are taped for irrigation through various types of wells. There is a good net work of canals from the perennial source providing irrigation. The area is suitable for all types of crops and a major portion is cultivated. Potential sites for plantation programme are field boundaries, roadsides (strip forests), canal banks, etc.

v. *Sub-humid to humid eastern and south-eastern uplands*—Though many black soil areas have high degree or fertility but the uplands are rather poor and are somewhat sandy on slopes. Uplands are mostly productive with a good monsoon season. The soils are exceedingly sticky when wet and pose problems of tillage when wet and also when dry. Owing to considerable contraction, large deep cracks are formed. There are orchards of Coconut, Arecanut and Banana in the area. The natural forest vegetation is very much degraded forming open canopied scrub forestlands. Pressure on the lands for fuel and agriculture is severe. For plantation, roadsides, community lands and hill-slopes are the most potential sites alongwith orchards.

VI *Arid Western plain*—It comprises of the parts of Rajasthan, Haryana, Gujarat, Dadar and Nagar Haveli. The rainfall is low and erratic falling in discontinuous events and thus, restricting plant and animal growth and productivity. The soils are mainly sandy to loamy sand with pockets of sandy loam to clay loam in low lying areas. The soils are characterised hy high content of soluble salts, high pH and low organic matter content. Water is the limiting factor for plant productivity. Though various fast growing species like *Eucalyptus camaldulensis*, *Acacia tortilis* and *Prosopis juliflora* have been tried, aboveground phytomass is very limited due to long and frequent drought spells. Human influences on the natural vegetation for fuel and other uses like fodder, fibre etc. have disturbed the ecological infrastructure of the region over which are superimposed the hostile climatic extremes. Though possibility of large scale rangeland improvement, sand dune fixation and afforestation, shelterbelts on roadsides and around farms, their proper management for balanced utilisation of soil-plant-animal resources is important. Cowdung and the agricultural wastes instead of being recycled into the soil are burnt for fuel. Though some communitylands locally called 'orans' are conserved, maximum protection is afforded at a few places where these are dedicated to some diety, otherwise they are badly eroded and sustain poor pollarded vegetation. These need priority for improvement under this programme.

VII.—*Semi-arid Central lava Plateau and Central highlands*—This region includes Maharashtra, Western and Central Madhya Pradesh and Union Territory of Goa, Daman and Dieu. The primary crops are bajra, in Maharashtra (Thana & Colaba), paddy is taken up. In rabi, Jowar is the main crop. The two primary landuses are mariculture and inland agriculture. There is a great possibility of developing farm foresty in the region and intensive collection of germ plasm of important fruits like mango.

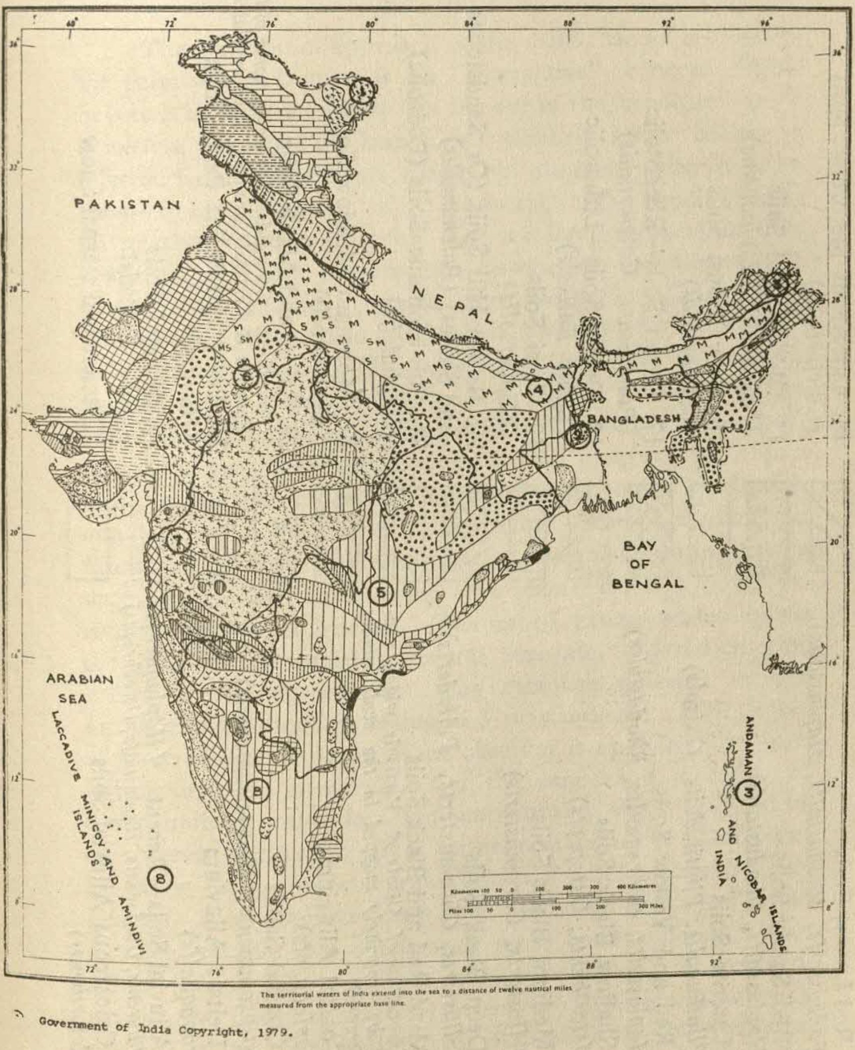
VIII. *Humid to Semi-arid Western ghats and Karnataka plateau*—It comprises of Karnataka, Tamil Nadu, Kerala, Pondicherry and Lakshdeep Islands. The soils vary from poor, thin, gravelly and light textured uplands to much fertile, deep, dark varieties of plains and valleys. Paddy, Sugarcane, Vegetables, Arecanut and several plantations are the main croas under irrigation while Jowar, Millets, Pulses, Groundnut are grown under rainfed conditions.

The lateritic zone includes both high level laterites resting on the rocks from which they have been formed and low land laterites formed in by way of detrital deposits. While at low elevations, paddy is grown, at higher elevation, Tea, Chinchona, Rubber etc. are grown. The zone also includes hilly areas where potato and plantation crops such as Tea, Coffee and Vegetables, various spices and condiments are grown in addition to various oil yielding species like *Eucalyptus* (Blue gum), Wattle (*Acacia mearsnii, A. dealbata, A. moleissima*), aromatic and drug plants. It appears that although this zone requires diverse landuses, depending upon the soil type, ecological consequences of such a diversified landuse need be explored for long term management and use.

Measuring Landscape Esthetics : The Scenic Beauty Estimation Method

Problem of measuring scenic beauty has only recently become a major concern. The proliferation of various techniques during the past few years reflects needs for a more substantive way to evaluate scenic resource. Many techniques have been developed without adequate consideration of scientific criterion tradionally associated with measurement systems. Objective measurement would place scenic beauty as a resource on a more equal footing with other more tangible resources and would also provide better justification for landuse decisions.

One of the methods, the SBE Method measures public "perceptual preference" for various landscapes through a carefully defined system of rating color slides, representative of these landscapes. It is based on the contention that scenic beauty judgements result from the interaction of observer perception and observer standards.



The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

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1. Humid Western Himalaya
2. Humid Bengal Assam
3. Humid and Himalayan region and Bay Islands
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5. Sub-humid to humid—Eastern and South-Eastern Upland
6. Arid Western Plain
7. Semi-arid Lava plateau and Central Highland
8. Humid to semi-arid Western Ghats and Karnataka plateau

LEGEND

Soil Types. (after AISLUS map)

▩	1. Red Loamy Soils (*Padeustalfs, Rhodustalfs, Haplustalfs*)
▥	2. Red Sandy Soils (*Haplustalfs, Rhodustalfs*)
░	3. Laterite Soils (*Plinthuqults, Plinthudults, Oxisols*)
⁘	4. Red and Yellow Soils (*Haplustults, Ochraquults, Rhodustults*)
▥	5. Shallow Black Soils (*Ustorthents, Ustopepts*)
▒	6. Medium Black Soils (*Pellusterts, Chromusterts*)
▥	7. Deep Black Soils (*Pellusterts, Chromusterts, Pelluderts*)
⌄ ⌄ ⌄	8. Mixd Red and Black Soils (*Association of Alisols & Vertisols which cannot be separately mapped in the scale under reference*)
T T T	9. Coastal Alluvium (*Haplaquents*)
■	10. Coastal Sands (*Ustipsamments, Quartzisamments*)
▤	11. Deltaic Alluvium (*Tropaqualfs*)
M M	12. Alluvial Soils—Recent (*Haplaquents Ustifluvents, Udifluvents, Haplustalfs, Ustochropts*)
▨	13. Calcareous Alluvial Soils (*Calciorthents*)
▧	14. Calcareous Sierozemic Soils (*Calciorthids*)
▤	15. Old Alluvial Soils (*Paleustalfs, Haplaquents*)
▤	16. Grey Brown Soils (*Calciorthids*)
▩	17. Desert Soils—Rhegosolic (*Psamments, Calciorthids*)
░	18. Desert Soils—Lithosolic (*Lithic Entisols*)
▥	19. Terai Soils (*Haplaquolls*)
▨	20. Brown Hill Soils (Or Sandstones and Shales) (*Palchumults*)
▤	21. Sub-Montane Soils (Podsolic) (*Hapludalfs*)
▦	22. Mountain Meadow Soils (*Cryoborolls*)
S S	23. Saline and Alkali Soils (*Salorthids, Salargids, Natrargids, some of the Entosols & Vertisols are also Salic or Natric*)
○ ○ ○	24. Peaty and Saline Peaty Soils (*Histosol*)
▒	25. Skeletal Soils (*Lithic Entisols*)
□	Glaciers and eternal Snow

The conceptuol approach of the SBE Model is based on the permise that beauty is an "interactive" concept. Scenic beauty is a neither entirely "in the eye of the beholder" nor is it solely a proper of the landscape. Rather, scenic beauty is inferred from a judgement made by a human observer in response to his perception of a landscape. The scenic beauty judgements depend only on the perceived properties of the landscape and the judgemental criteria of the observer. If one area is consistently judged, more beautiful than another, the areas are assumed to have different values on the perceived scenic beauty scale. The criterion component of the SBE model is also represented by a value (or a set of values) on the perceived scenic beauty dimension. These criterion values, brought to the judgement situation by the observer, are important components of any evaluative judgement. An observer may express his judgement of landscape scene by a numerical rating. Each landscape scene can be assigned a rating from a scale–for example, 1 (extremely low scenic beauty) to 10 (extremely high scenic beauty). The use of rating scale requires the observer to establish several separate, ordered criterion values. Different observers may establish different criteria for assigning ratings. A rating of 3 may indicate a high degree of perceived scenic beauty if the observer is applying very high (stringent) esthetic criteria. On the otherhand, a rating of 8 may indicate rather low landscape beauty when assigned by an observer having low (lax) esthetic standards). Difference in rating may indicate true differences in perceived scenic beauty. If an observer rates one landscape scene as 3 and another as 8, the two landscapes must have different scenic value (unless his criteria is suddenly shifted). A problem arises here, however, when we attempt to determine how much of a difference of scenic beauty is indicated by these ratings. A different observer might, for example, rate the first scene as 6. Does the 5 points spread in judgements given by the first observer indicate a greater difference in scenic beauty than the 1 pt. difference in the second observer's ratings Scenic Beauty Estimates (SBEs) are relative scale values calculated from each observer's ratings of a number of different land-scape scenes. SB Values are derived from judgements made by a number of observers for a variety of landscapes. Observer's ratings are adjusted to take into account different criteria. The resulting SBEs provide a quantitative index of the perceived scenic beauty of the landscapes.

Application of this method for landscape evaluation involves 3 main steps; i) representing landscapes by colour slides; ii) presenting slides to observers and iii) evaluating observer judgements Color prints of even sketches (if properly validated) could also be used. Steps 1 & 2 may be eliminated by transporting the observers to the sites.

Validity of any measuring instrument is a complex problem. Only repeated demonstrations of applicability and utility can truly validate a method.

Extension of this method finds place in esthetic mapping. The contours represent lines of equal scenic quality. Prediction of scenic beauty based upon manageable landscape features is still in experimental stage.

Priority Areas for Plantation

I. Plantation for shade and ornamentation—

1. *Roadside and avenue plantations*—Shade bearing, ornamental and fruit plants on highways and link roads in villages need be planted. These have recently formed "Strip forests" in some states like Haryana and Punjab. Also ornamental and fodder species may be planted for landscaping.
2. *Community Centres*—Areas meant for recreational activities such as commmunity meetings of Gram Panchayats, block development council, tombs, hospitals, schools, community wells, gardens and places of religious worship as temples, mosques, churches etc. All these places need be planted with shade bearing and ornamental species.
3. *Canal bunds*—Shade bearing species need be planted for reducing water loss through evaporation, reducing wind velocity and for bund stabilisation.
4. *Railway lines and yards*—Shade bearing and ornamental species for shade, bioaesthetic value and economic returns, may be planted.
5. *Rural and urban homes*—Shade bearing, ornamental and fruit bearing plants in urban homes and shade bearing plants for farm houses which could provide fodder for the cattle during lean period of fodder availability and thorn for fencing of houses.

II. Plantation for soil conservation, anti-erosion measures and habitat improvement—

Stabilisarion and afforestation of some refractory sites such as rocky areas, sand dunes, waterlogged areas, torrent beds and torrent banks, landslips, roadside eroded areas and mine spoiled habitats in the hills and saline depressions, etc.

III. Plantation on farmlands for farm forestry, shelter-belts and wind breaks on field magins and bunds. Upright and straight boled plants without much crown are preferred. These should not provide nesting place for the birds. Top feed species and fast growing species to meet the fuel requirements of the farmers are preferred which could also be raised as mini-woodlots.

IV. Plantation for sylvi-pastoral management of community *Gocharlands* for village grazing animals. Shade bearing palatable and nutritive leaf-fodder tree species compensate for the nutritive forage requirement of villagers' bovine population during lean periods of forage availability. Proper grazing management practices and management of these lands after inprovement need be evolved in view of socio-religious considerations of reduction in cattle population.

1. **Plantation for Shade and Ornamentation**

1. *Roadside plantation*—Tree planting on avenues have been practised in India from ancient times. Manu prescribed planting of broad-leaved trees of Bargad *(Ficus benghalensis)*, Gular *(F. glomerata)*, Pipal *(F. religiosa)*, Palas *(Butea monosperma)*, Semal *(Bombax ceiba)* and Palms along the boundary of villages for avoiding family disputes. In Manusmriti, a fine of 1000 coins has been prescribed for felling of fruit tree, 500 coins for flowering tree and 100 coins for other trees. Kalidas described a scheme of flowering trees in Raghuvansham when Raghu went to Ashram. The Moghuls planted trees of *Ficus infectoria* (Pilkhan), *Tamarindus indica* (Imli), *Azadirachta indica* (Neem), and *Bassia latifolia* (Mahua) on major roads in the plains and the roads were given a curve after every mile. Cheenar trees *(Platanus orientalis)* along the Jhelum were planted. The British too planted major highways in the country with shade bearing plants and the Public Works Department was entrusted with the Horticultural Programme also. Inspite of all these efforts, avenues comprising of both National and State highways and village link roads remained to be planted for three primary reasons, viz. utilitarian, bioaesthetic and as natural reserves and asset.

A. Utilitarian

a) *Shade*—For about 6-8 months, the roads in our country are scorched by hot sun. The trees provide shade for pedestrians and cattle population. A shady avenue is a welcome thing even to people travelling in luxury coach. The trees on roadside provide shelter to farmers and villagers working in the neighbouring field where they can find rest during working recess. In the country scores of farmers and other workers squatting under the shade of roadside trees during summer noons is a common sight.

b) *Protection from erosion by wind, rain and snow*—The soils of the roadsides are firmly protected by the roots of avenue plants thus saving it from erosion, both by water and wind. The canopy cover of trees mechanically reduces the force of wind and protects the soil. Hilly roads are protected by plants from getting slipped and thus, serve the purpose of contours by breaking steepness of slope.

c) *Protection of road surface*—Crown of trees protect the road surface by reducing effect of falling heavy rains, hailstorms or by scorching summer heat.

d) *Road safety*—Presence of roadside trees make the edges and curves of the roads conspicuous thus making driving safe and easy. These trees when painted with a white band make a natural guide for easy driving. In the hills, roadside trees have often stopped and supported many falling vehicles.

e) *Windbreaks*—Trees along the roads, if planted scientifically, make a belt and break the force of wind. This is particularly useful in desert and rocky areas where barren plain streches for long distances. Such areas could by planting windbreaks, be profitably utilised for many purposes. Sometimes, the roadside vegetation serve as a good nucleus for growth and expansion of vegetation to grow.

f) *Fruit and fodder*—Plants like *Syzygium cumini* (Jamun), *Mangifera indica* (Am), *Tamarindus indica* (Imli), *Bassia latifolia* (Mahua) provide fruits for travellers. If long avenues are planted, commercial exploitation could be economic. Similarly, fodder trees provide leaf material for cattle and goats. *Acacia* *nilotica* ssp. *indica, Azadirachta indica, Ficus glomerata* and other species provide valuable fodder on the plains to passing animals thus providing the concentrates during the lean fodder availability season. Some of the flowering trees on roadsides would attract honey bees and apiary could be developed on a large scale by planting several species like *Syzygium cumini, Cassia fistula* and *Jacaranda mimosaefolia.*

g) *Fuel*—Some of the States like Haryana and Punjab have utilized their roadsides for raising "Strip forests", which are regularly exploited and managed on scientific forestry, Examples of *Eucalyptus* plantations could be followed by other States since it provides much needed fuel wood on short rotation basis. Fuel yield from strip plantations in Haryana have yielded about 7 metric tonnes per hectare for a rolation of 7 years. Similarly, indigenous species like *Dalbergia sissoo, Acacia nilotica* ssp. *indica, Tamarix articulata*, have a vast potential.

h) *Educative value*—Roadside trees have a tremendous educative value both for travellers and children which provide them the milieu to study and learn about the various trees, their phenology and products. It is further suggested that some national highways should be given names for the trees planted which would provide opportunity for the travellers to know more about them. There are instances in the country when the roads have been named after the plants on them such as "Amaltas road", "*Jacaranda* road", "*Millingtonia* road", "Oak groove", "Pine groove", etc. Such a practice would help in familarising typical roadside plants to common man.

B. *Bioaesthetic*

Roadside trees are the source of beauty for the city. A well planned avenue gives a beautiful view from the road which sometimes look like a tunnel with a sprinkle of sunlight. Since northern India is characterised by long dry summers (April-June) and distinct winters, trees with spreading crowns and evergreen foliage have to be mixed with winter deciduous trees. In fact, phenological characters of tree species, like flowers of *Butea monosperma, Bombax ceiba, Erythrina indica* in northern India mark the advent of spring season while leaf fall marks the arrival of winters.

Trees producing flowers of different shades and in different seasons are to be used to break the monotony of pure avenues of evergreen foliage trees. Such groups of flowering trees could be planted after certain distance or at the crossings or near the habitations. For bioaesthetic planting, colour harmony is necessary and, therefore, a sequence of violet, indigo, blue, green, yellow, orange and red is pleasing as one colour merges in the next. Red *(Delonix regia, Erythrina suberosa, Butea monosperma)* is colour of passion, yellow *(Cassia fistula, peltophorum)* is of light, while blue *(Jacaranda ovalifolia)* has passive or soothing quality. Orange add warmth and gaity. Pure avenue of one species for long streches also sometimes look harmonius and pleasing since skyline will look regular and wave like general appearance will improve. Moreover, replacement of species will be predecided and easy. Near cities, innerline could be of *Delonix regia, Cassia fistula, Jacaranda mimosaefolia, Erythrina suberosa, Spathodea* and *Eugenia operculata* while outerline of shade trees with dense foliage such as *Tamarindus indica, Polyalthia putranjiva, Mimusops, Ficus (retusa, infectoria)* and *Azadirachta indica,* would be most pleasing. On outer roads, pure avenues will provide shade and furnish green background for pink red, crimson and yellow of flowering trees in frontline. Multirow of *Eucalyptus* create a beautiful effect on alluvial plain areas while *Populus* avenues *(P. tremula, P. alba)*, Lombardi poplar *(P. nigra), P. deltoidea, P. euramenica, P. italica,* in Kashmir valley are extremely pleasing.

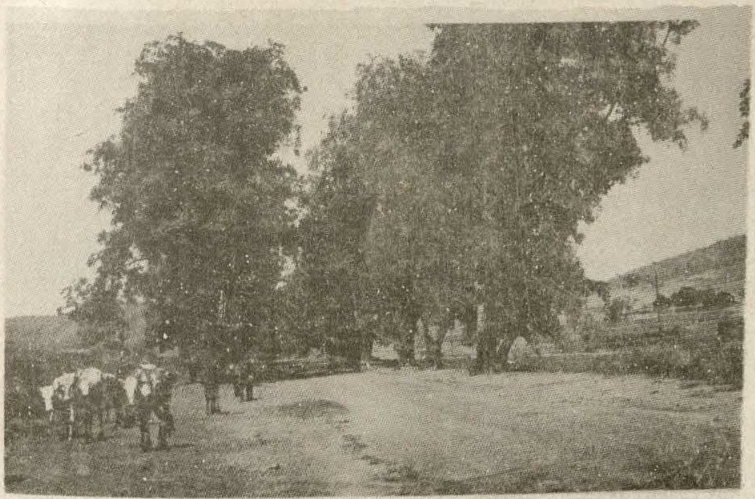
Considerations for avenue plantations—Some of the general considerations for raising avenue plantations that should be borne in mind are as below—

1. The trees should have a clean bole for atleast 3 m so that their first branches do not obstruct high loaded vehicles and also the view.
2. The trees should have dense crown cover so that they provide good shade and protection from rain, hail and sun.
3. Ecological considerations of site characters and climatic pattern should be kept in view before selecting species for plantation. This, if not taken into consideration, results

in total failure of the plantation and thus, complete disappointment.

4. The trees should not have a very spreading crown which may obstruct the free growth of opposite rows of trees.
5. Root system of the trees selected should not be very shallow nor very spreading. Trees with deep root system, are the best for they can survive unfavourable climatic conditions by tapping water from deeper soil layers. They do not fall down easily with gales and storms and obstruct traffic. Too much spreading root-system sometimes damage the masonry work of the road.
6. The trees should not have aerial roots such as in *Ficus benghalensis* since hanging roots obstruct traffic and cause accidents. If present, those should be removed regularly.
7. Trees should alternate with each other on opposite side of the road but should not be opposite.
8. Too many species should not be mixed within short distances otherwise this makes management difficult. While selecting species care should be taken that the produce would form a basis for small agro-industries such as Mahua, Neem, Karanj, Imli, etc.
9. The selection of trees should be made based on their phenology such as roadside trees should not have leaf-fall during summer and rainy season when the shade is most needed. Trees having unusually heavy litter fall, should be avoided since at makes the road dirty. Similarly, birds nesting on the tree (as in *Ficus glomerata*), make the roads dirty.
10. As far as possible, the trees should not be thorny since it makes journey hazardous by damaging the tyres of vehicles, and give trouble to pedestrians. Therefore, species like *Prosopis juliflora* and *Acacia tortilis* should be avoided.
11. Very soft wooded and brittle trees should not be planted since they break away in storms and block the traffic. Plants like *Millingtonia hortensis*, *Syzygium cumini*, *Albizzia lebbek*, *Cassia siamea*, and *Ficus glomerata* break easily in wind storm. These result in road block and are a menace

Eucalyptus along the railway lines provides fuel and better landscape.

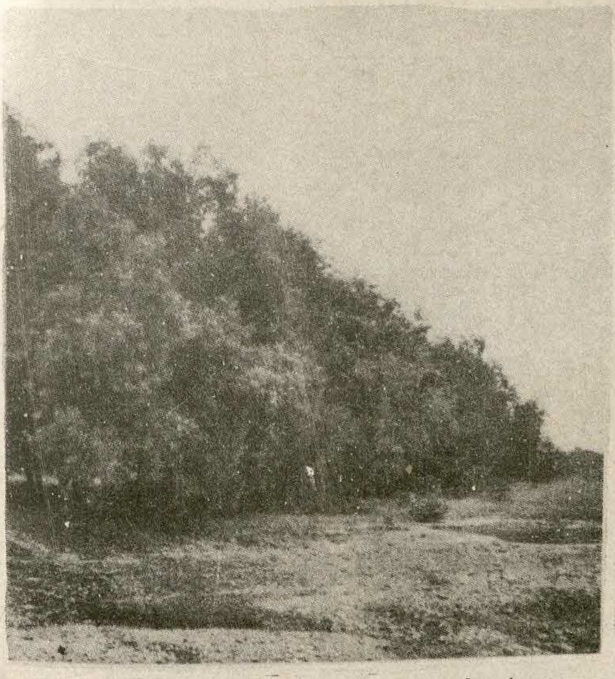


Pongamia glabra planted on roadside gives a tunelling effect.

Acacia nilotica ssp indica is a common species on the roadsides in some parts of the country.

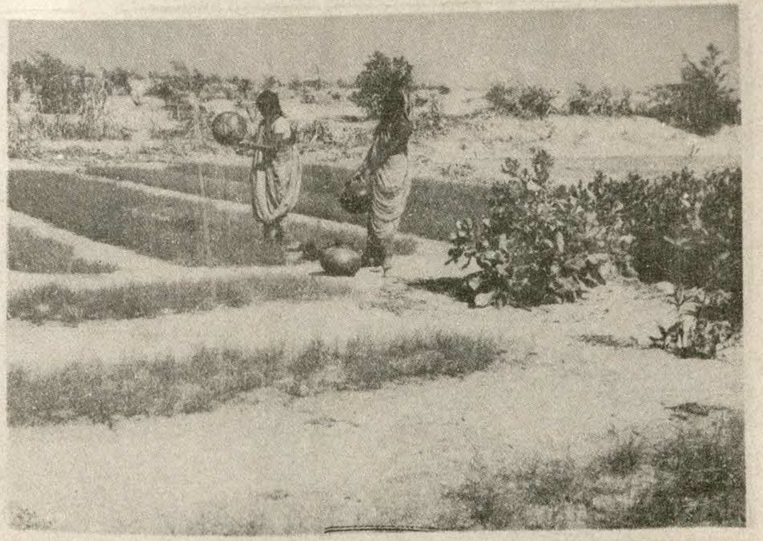
Acacia tortilis—from Israel is both drought and frost resistant as compared to Prosopis juliflora and is largely used for afforestation of sand dunes in arid tracts of Rajasthan, Haryana & Gujarat States.

Couropita guianensis is an ornamental flower used in peninsular India.



8-year old plantation of Acacia auricuaeformis on the foreshore areas of Tilaiya Dam D.V.C., Bihar (Photo Courtesy Shri A.K. Chatterjee, Forest officer DVC)

Coconut plantations successfully established for stabilisation and plantation of coastal dunes by Orissa Soil Conservation organisation



Nursery being watered by the perched sweat water present 1-2 m below the surface in coastal areas. Notice plantation of Anacardium occidentale, Casuarina and Coconut on dune areas.

Acacia planifrons is suitable for afforestation of coastal dunes

Anacardium occidentale-the cashew has been used both for soil conservation and as a cash crop in coastal areas for dune afforestation.

to lines of passers. Hence these should not be planted on roadside avenues.

Tree forms and their design value

The following tree forms have been designed (Ahuja 1977) for their different values in landscape :

Group A : Round	Broad	Square	Spreading
Ailanthes excelsa	*Ficus infectoria*	*Mimusops elengi*	*Schleichera trijuga*,
Azadirachta indica			*Cassia javanica*
Tamarindus indica			*Lagerstroemia flos-reginae*,
Albizia procera			*Albizia lebbek*
Emblica afficinalis			*Plumerias*

Round and broad tree forms are used for tracing effect of their branches and foliage. Heavy foliage and thorny habits are troublesome at leaf-fall and hence its use as shade tree on roads is not desirable. Large leaves and light foliage permit light penetration and good circulation of air in park and look more graceful.

Pine trees with rounded appearance blend well with round-shaped deciduous trees. Dark green foliage conifers with round forms are better suited in landscape area than horizontal flat topped. Round, Broad and Square trees tend to have high branching which allow passage under canopy and guide a person's path through a landscaped area and link major features of planting and design.

Group B : Conical, Columnar, Tapering and Arrow :

Mimusops hexandra
Heterophragma adenophyllum
Millingtoma hortensis
Terminalia arjuna
Grevillea robusta
Erythrina indica } Columnar to conical
Mangifera indica

Needle leaved, evergreen trees provide naturalistic landscape. They may by used for screening undesirable views and enframent to building. They also provide a background to emphase, colour, texture and forms of foreground elements and natural screen. These are considered best good wind breaks.

Spathodea campanulata *Bauhinia purpurea*	Conical to round
Bombax ceiba	Conical
Polyalthia longifolia	Conical to tapering
Casuarina *Auracaria excelsa*	Arrow

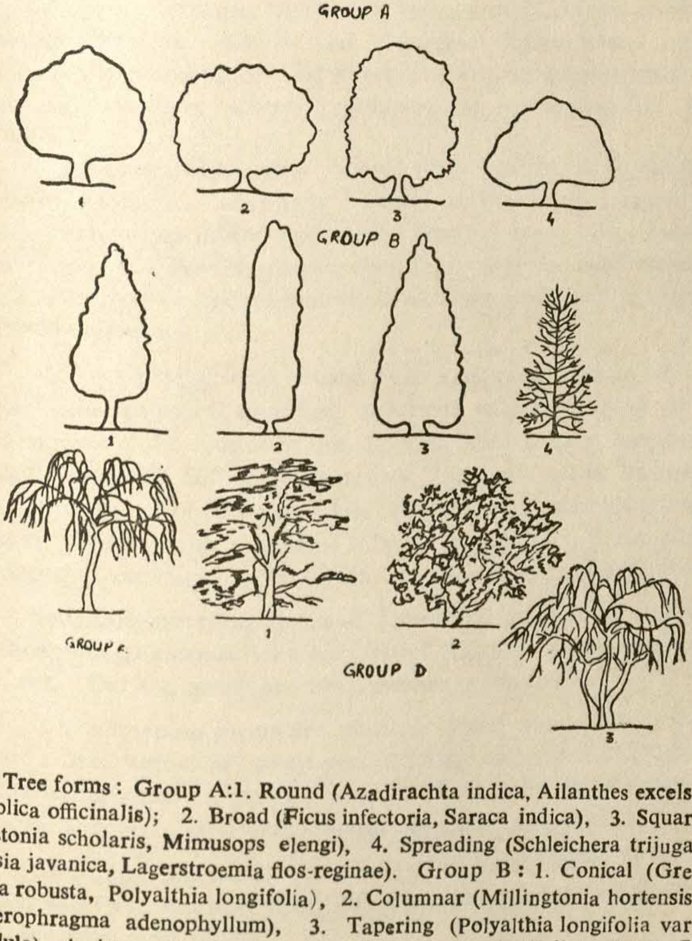
The evergreens provide texture and colour to planting composition when deciduous have shed their leaves. They create outdoor space by defining areas clearly. When planted in any garden, become a dominant feature and difficult to blend.

Columnar conifers are most difficult to use in landscape. Their vertical and narrow habit does not mass into grouping. Their typical form also does not relate well to other forms. These provide a good screen as hedge. Sometimes used as specimen trees.

Columnar forms may be used as punctuation mark and for local effects. Usually they tend to draw the eye to wards object being screened. Thus their use as screening plant is recommended in restricted places.

Pyramidal forms in groups obstruct undesirable views very effectively upto ground level. They create bold views very effectively upto ground accent in any planting dominated by deciduous trees. They also serve as good background for a flowering tree in the foreground, a character used in Japanese gardens. Pyramidal forms are broad in relation to their height and call attention to themselves. They might serve to focus attention on some plants.

Group 3: Weeping froms—*Putranjiva roxburghii*, *Tecomella undulata*, *Millingtonia hortensis*, *Hardwickia binnata*, *Polyalthia longifolia* var. *pendula* and *Saraca indica*, have either dropping branches or leaves. Their use in landscape is related to their main form as columnar or conical etc. but *Salix* and *Callistemon* are typical examples of weeping form.



Tree forms : Group A:1. Round (Azadirachta indica, Ailanthes excelsa Emblica officinalis); 2. Broad (Ficus infectoria, Saraca indica), 3. Square (Alstonia scholaris, Mimusops elengi), 4. Spreading (Schleichera trijuga, Cassia javanica, Lagerstroemia flos-reginae). Group B : 1. Conical (Grevillea robusta, Polyalthia longifolia), 2. Columnar (Millingtonia hortensis, Heterophragma adenophyllum), 3. Tapering (Polyalthia longifolia var. pendula), 4. Arrow (Auracaria excelsa, Casuarina equisetifolia) Group C: Weeping C(allistemon lanceolatus). Group D : 1. Horizontal (Millingtonia hortensis), 2. Contorted (Butea monosperma), 3. Multitrunk (Callistemon lanceolatus) (after Ahuja, K.G. 1977).

Weeping forms are known for their beauty, gracefulness, femining, softness, sorrow and elegance. These forms may occasionaly be used for special effects and convey passive serene mood and are best where relaxation or contemplation is desired.

These present best view when seen against a group of contrasting foliage. They may be used to break up formality of design but when mixed with round headed trees, they loose their character. Weeping trees, therefore, may be used either single or in rows or groups against a building wall or on edge of border planting.

Mostly weeping form is used as a specimen tree in landscape. The sculptural qualities, spectural effects created are well-known. *Salix babylonica* use is well known over hanging cascade where the falling of a moving lines of water harmonize with those of willows. Use of such trees near stagnant pool of water or in middle of a lawn as specimen plant conflicting with surrounding flat strata of water or lawn is common.

Sometimes weeping forms of teees are introduced into a landscape to produce sudden contrast of forms, thus giving an account. But too many accents become monotonous.

When weeping forms are planted along roadways, they create a dark tunnel of green-ness adding to apparent length but creating some darkness. Such an effect may be a desirable character in a particular situation or in a composition.

Group 4 : Horizontal branching, irregular form or contorted form and multiple trunk of multiple stemmed or clump growing trees and others.

Certain forms that do not blend well with surrounding landscapes may be used only as specimen tree. *Araucaria excelsa*, horizontal branching conifers (Pine) are very useful in certain landscape composition.

They can make a loose screen when planted in staggered rows and may also serve as background planting for flowering trees. This form with lacy branching habit may be advantageously used in dividing a large montonous units into smaller units.

Tree with horizontal branching may also be used for accents in naturalistic landscape. This form may be used as specimen tree.

Contorted forms—Some trees have irregular forms such as Pines, *Cassia fistula*, *Jacaranda*, etc. Others take up this form due to unfavoured growing conditions. The later become trees of strong individuality and are best used as single specimen with enough space round them. These have distinctive characteristics and are also called picturesque trees. They may include spreading, weeping and arrow forms. These picturesque trees have various meaning to various observers. Different eyes see different pictures in them. This form has a grace of its own and a distinctive character and draws attention to itself through individual character. Hence these are ideal for accents. Contorted forms when planted near a walk create interest and enframe the view.

Multiple Tree trunk—This type of clump growing has its own merits in a landscape composition. They can divide an area into two units. Greater ground weight with several stems, rather than one, show solidity at the base. These serve as a special feature in a composition. Besides there can be other forms.

Vase-shaped (*Adansonia digifata*) angular branching (*Ginkgo biloba*, Umbrella-shaped (*Albizia lebbek Acacia planifrons*) etc. have their own characteristics but they all have various uses in different com- positions.

Choice of species vis-a-vis site habitats—Avenues in towns and cities are chiefly ornamental though shade is needed but is not of primary consideration. Therefore, plants which provide some shade, but are showy, are generally preferred. Another consideration which is kept in mind for selecting trees for city avenues is that it should not be tall enough to interfere with the electric wires and balcony of the buildings etc. On village link roads, main consideration could be that the selected trees should provide enough shade to travellers. They should also provide base for some agro-industries such as seed collection for oil (*Azadirachia indica*, *Pongamia glabra*) and starch (*Tamarindus indica*), should provide fruits (Amla, Mango, Imli) and fodder for bovine population (Kikar, Siris). Some of the plant species providing dense shade are Pipal (*Ficus religiosa*), Banyan (*F. benghalensis*), Am (*Mangifera indica*), Shisham (*Dalbergia sissoo*), Imli (*Tamarindus indica*), Gular (*Ficus glomerata*), Neem (*Azadirachta indica*), Jamun (*Syzygium cumini*) and Karani (*Pongamia glabra*). Much importance is not given to showy flowers.

Common plants for national and state highways, generally recommended are Gular (*Ficus glomerata*), Amaltas (*Cassia fistula*) and *Erythrina* alternating with shade trees like *Jacaranda mimosaefolia*, *Spathodea* sp., *Bauhinia* sp. and *Polyalthia longifolia* or *Eugenia operculata*. Choice should be restricted to one species for each street. Tall trees like *Eucalyptus* spp., *Millingtonia hortensis* are not suitable as they interfere with electric and telephone lines. Medium trees like *Polyalthia longifolia*, *Putranjiva roxburghii*, *Mimusops hexandra* are ideal for shade. In big cities, trees of *Tamarindus indica*, *Mimusops hexandra*, *Azadirachta indica*, *Polyalthia longifolia* are most suitable.

Therefore, on majot main roads, Kikar, Arjun, Siris (*Acacia nilofica sspindica Terminalia arjuna*, *Albizia lebbek*), Bakain (*Melia azadirach*) and Neem (*Azadirachta indica*) aret he main species while for minor district roads, Kikar and Shisham is planted in 1-3 rows; for link roads, Kikar is the main pecies. For avenue on canal, Shisham, Kikar, *Eucalyptus* and *Toona ciliata* are pre- ferred. For railway strips, Kikar is the most common species. Among avenue of ornamental plants, *Delonix regia*, *Erythrina suberosa*, *Lagerstroemia flosreginae* with shrubs of Kaner (*Nerium indicum*), *Cassia glauca*, *Andromeda ovalifolia*, *Tecoma stans*, *Bougainvillea* spp., Shoe flower (*Hibiscus rosa-vinensis*) and *Pongamia*, are most preferred.

Waterlogged situations—Apart from the various agro-ecological situations, roadsides may also provide varied site conditions for plantations. For successful plantation, such situations are important to be kept in view while choosing the species and for the soil working. Choice of trees has to be linked with site condition. Moisture loving *Lagerstroemic*, *Salix*, *Sapium sebiferum* are to be used for canal side avenues, *Eucalyptus rost-*

rata, willows and *Tamarix* for waterlogged areas, *Tecomella undulata*, *Albizzia lebbek* and *Prosopis* for poor sandy soils, *Cochlospermum gossypium*, *Cassia fistula* for rocky sites and *Butea monosperma* (Dhak) for alkali soils. Another important factor on roadside plantation is protection of the plants from bovine population in early stages of its growth. Therefore, modification in soil working techniques could reduce the cost of tree guards or fencing usually erected for saving such plantations.

In Haryana, pure avenues of *Eucalyptus*, *Dalbergia sissoo* and *Albizia lebbek* have been created on national highways. Even pure avenues of *Acacia nilotica* ssp. *indica* having yellow flowers on canal, drains and bund is good. On road crossing approach to towns and cities, sequence of planting on both sides of road is *Saraca indica*, *Jacaranda mimosaefolia*, *Delonix regia*, *Cassia fistula*, *Colvillea racemosa* and *Sesbania grandiflora*. These give flowers of different shades in February/March, March/April, April/May, October/November and November/December. Other schemes are of *Grevillea robusta*, *Erythrina indica*, *Cassia nodosa*, *C. marginata*, *Jacaranda mimosaefolia* and *Lagerstroemia*.

Various schemes for planting avenues could be evolved depending upon their season of flowering and defoliation. Some of the schemes are given below (after P.C. Chatterji in Anonymous 1973).

Scheme No. 1	Fls. February/March		
Bauhinia variegata (Purple mauve)	*B. variegata* (White)	*B. kurzii* (Light magenta)	*B. variegata* (Light purple)
Scheme No. 2	Fls. March-April.		
Spathodea nilotica (Or. crimson)	*Erythrina indica* (Scarlet)	*Spathodea indica* (Or. crimson)	
Scheme No. 3	Fls. April		
Jacaranda ovalifolia (Blue)	*Grevillea robusta* (Yellow)	*J. ovalifolia* (Blue)	
Scheme No. 4	Fls. May		
Cassia fistula (Yellow)	*Delonix regia* (Scarlet/Or.)	*Cassia fistula* (Yellow)	
Scheme No. 5	Fls. May-June		
Cassia nodosa (Pink)	*C. marginata* (Pink red)	*C. nodosa* (Pink)	

Scheme No. 6	Fls. October	
Peltophorum ferrugineum (Yellow)	*Colvillea ramosa* (Or. Red)	*P. ferrugineum* (Yellow)
Scheme No. 7		
Acacia auriculaeformis (Yellow)	*Thespesia populnea* (Red purple)	*A. auriculaeformis* (Yellow)

One of the common situations met for roadside plantation is the waterlogging since roadsides have been dug for excavating the earth for putting on road edges. This type of situation is common throughout the plains in the country. Planting of such sites after proper drainage, is now a common practice. *Eucalyptus robusta* is usually recommended for waterlogged areas in South India while another species is *E. rudus*. *Eucalyptus rostrata* and *E. hybrid* have been successfully grown on badly drained swampy areas of Tamil Nadu. In Assam, *Barringtonia acutangula* has been found to grow well in the midst of swamps while in Bengal, *Bischofia javanica* has been successfully grown in wet areas. Sandy waterlogged soils of Orissa, Andhra, Karnataka and Tamil Nadu are covered with *Casuarina equisetifolia* while *Syzygium cumini* is planted on mounds in swamy areas of Orissa state. *Tamarix articulata* tolerates waterlogging to some extent being native of riverain habitat while *T. dioica* also tolerate saline conditions. *Sapium sebiferum* has done well in swamy areas of Dehra Dun and other Tarai regions. *Cassia siamea* did well in drained plots while *Zizyphus mauratiana*, *Butea monosperma* and *Acacia nilotica* ssp. *indica* grow frequently in areas liable to inundation. Species which could grow on badly drained areas are *Dalbergia latifolia*, *Lagerstroemia lanceolata*, *Terminalia tomentosa*, *Syzygium cumini*, if sown on ridges parallel to drainage, while in certain localities *Cedrela serrata*, *Balanites aegyptirca*, *Pterocarpus dalbergioides*, *Lagerstroemia hypoleuca* succeeded in addition to species like *Randia ulginosa*, *Phyllanthus reticulatus*, *Grewia nudiflora*, *Leea macrophylla*, *Mallotus phillipensis* in low lying waterlogged areas. *Eucalyptus rostrata* is recorded to have a high rate of transpiration. Similarly, *Salix tetrasperma*, *S. babylonica* and *Tamarix* sp. can stand waterlogging and are highly suited for waterside planting. Similarly plantations with broadleaves have high transpiration rate.

Among the trees resistant to saline conditions, mention may be made of *Butea monosperma* (Palas) which grows successfully on Usar soils. *Bassia latifolia* (Mahua) is moderately salt resistant and can grow on slightly saline soils yielding good timber. *Eucalyptus citriodora*, *Azadirachta indica* (Neem), *Emblica officinalis* (Amla), *Psidium guajava* (Amrood) are moderately salt tolerant. *Phoenix dactylifera* flourishes on brackish soil while *Tamarix articulata* (Farash) thrives in saline soil. Similarly *Thespesia populnea* occurs on the backwaters in Kerala and Tamil Nadu.

Alluvial plains with Kankar Zone

Another situation commonly met for avenue plantation in arid and semi-arid zones is the shallow soil depth. On old alluvial plains effective soil depth is very important. These soils are generally characterised by the presence of a kankar zone varying at depth from 1-3 m. This zone consist of Calcium Carbonate nodules which sometimes get cemented and form an unindurated zone where the roots cannot penetrate. Though no systematic scientific studies are available on the growth pattern of tree species under varying soil depths and types of kankar zone, observations made by the author might be valuable. Under Jodhpur conditions, plantations of *Delonix regia* and *Dalbergia sissoo* failed completely after 5-6 years of their successful survival and growth. Plants of *Jacaranda ovalifolia* showed pollarded growth from the very beginning while plants of *Delonix regia* and *Dalbergia sissoo* started drying from the top after 5-6 years and ultimately died. Perhaps this is the time when the roots reached the kankar zone and could not penetrate it. On the other hand, there are several indigenous species which could grow successfully under similar conditions, a few examples are *Prosopis cineraria*, *Acacia senegal*, *Balanites aegyptica*, *Azadirachta indica*, *Albizia lebbek*. Other phraetophytes recorded in Indian works include *Butea monosperma*, *Strychnos nuxvomica*, *Terminalia bellirica*, *Capparis spinosa*, *Salvadora persica* and *S. oleoides*. Manu recorded *Phoenix dactylifera*, *Syzygium cumini*, *Anthocephalus cadamba*, *Pongamia glabra*, *Mesua ferea* alongwith plants like *Vitex negundo*, *Saccharum*

spontaneum and *Vetiveria zizanoides.* Varahamira recorded *Tecomella undulata*, *Lagerstroemia speciosa, L. parviflora* in addition to the above species. Sometimes these species are used as indicator for underground water.

Roots of *Prosopis cineraria* when excavated show (Gupta, 1975) large extension both horizontally and vertically reaching upto 100-150 m depth, the species being a phraetophyte. Beautiful roadside plantations of *Azadirachta indica* and *Albizzia lebbek* could be seen on similar situations with proper soil working. Plants like *Prosopis juliflora,* the favourite of many, did not show much growth on heavy soils of Gujarat coast where forest department had to resort deep soil working.

Effect of frost—Another situation which one is likely to encounter for avenue plantation is damage by frost. Plants like *Azadirachta indica*, *Albizzia lebbek* need protection in early stages in extreme arid regions liable to frost like Sikar and Jhunjhunu districts of Rajasthan.

Studies on the arid zone trees (Muthana 1974) showed that frost damage is most severe on trees in the seedling and sapling stages. Frost susceptible species should not be established on areas with abundant weed growth since frost intensity is greater immediately close to ground than in areas free from ground cover. Frost hollows or pocket, i.e, low lying areas in which cold area settles and cannot drain-off or blow-off only frost resistant trees should be grown. Ordinarily indigenous species are well adapted and do not suffer outright from frost except in special circumstances when frost occur late in spring after the vegetative activity has started. Damage of late spring frost is common to young seedlings and fruit plants since the young buds are damaged. Seedlings growing in shade are not generally injured by late spring frost as compared to those in open. However, exotics suffer badly from both early and late frost since their apical branches may be killed. Tree species which frequently suffer from frost in north-west arid and semi-arid zones are *Prosopis juliflora* and *Azadirachta indica* but resprout. Therefore, it is necessary to protect them. Even 2 m high plants sometimes suffer. Other species recorded to have severely effected by frost are *Tecoma argentea, Caesalpinia*

coriaria, *Dalbergia multiflora*, *Glyricidia maculata*, *Acacia nilotica* ssp. *indica*, *Zizyphus mauritiana*, *Prosopis juliflora* (6 yr.), *Albizia lebbek*, *Acacia tortilis*, *Bauhinia purpurea*, *Kigelia pinnata*, *Pongamia glabra*, *Inga dulces*, *Cassia siamea*, *C. javanica*, *C. multijuga*, *C. fistula*, *C. glauca*, *Bauhinia variegata* (4 yr.), *B. hookeri*, *Bombax ceiba*, *Albizia odoratissima*, *A. mollisima*, *Erythrina indica*, *Calotropis procera*, *Ricinus communis*, Papaya, etc. Plants which are effected moderately include *Dichrostachys glomerata*, *D. nutans*, *Acacia farnesiana*, *Holoptelea integrifolia*, *Dalbergia sissoo*, *Acacia catechu*, *Cassia nodosa* and *Ficus benghalensis*. Some of the plants not effected by frost are *Tamarix articulata*, *Prosopis cineraria*, *Tecomella undulata*, *Capparis aphylla*, *Ailanthes excelsa*, *Zizyphus nummularia*, *Acacia tortilis* and *Dalbergia sissoo* (above 2 m).

For the hill areas, selection of plant species will largely depend on the elevation and would be somewhat different as for the plains. Plant species for various altitudes for hill road plantations are recorded as below:

Trees	*Bushes*	*Climbers*
1100 m		
Ailanthes excelsa	*Bougainvilla sp*	*Cestrum nocturnum*
Butea monosperma	*Hibiscus sp*	*Jasminum sp*
Bauhinia retusa	*Nerium indicum*	
Bombax ceiba	*Punica granatum*	
Toona ciliata		
Callistemon vimnalis		
Cassia fistula		
Delonix regia		
Grevillea robusta		
Jacarnda ovalifolia		
Moringa pterygosperma		
Morus alba		
Sapium sebiferum		
1100-1500 m		
Bauhinia sp.	*Hibiscus* sp.	*Cestrum nocturnum*
Bombax ceiba	*Punica granatum*	*Jasminum* sp.
Callistemon vimnalis	*Rhus cotinus*	*Vitis semicordata*
Cupressus sempervirens	*Spiraea canescens*	*Passiflora sp*

Fraxinus micrantha		*Bauhinia vahlii*
Grevillea robusta		
Lagerstroemia flosreginea		
L. parviflora		
Populus ciliata		
P. cassale		
P. niger (Lombardi poplar)		
P. italica		
P. deltoides (Kashmir)		
P. tremula		
P. alba		
Robiniv psudacacia		
1500-1750 m		
Fraxinus micrantha	*Desmodium* sp.	*Cestrum nocturnum*
Grevillea robusta	*Hibiscus* sp.	*Jasminum sp*
Lagerstraemia flos-reginea	*Spiraea canescens*	*Rosa moschata*
	Solanum sp.	*Vitis semicordata*
L. parviflora	*Woodfordia fruticosa*	
Prunus armeniaca		
P. *persica*		
Rhododendron arborum		
Robinia pseudacacia		
Salix babylonica		
S. wallichii (Kashmir)		
Ulmus villosa		
1750-1950 m		
Aesculus indica	*Desmodium* sp.	*Rose (climber)*
Cupressus sempervirens		*Cestrum nocturnum*
Fraxinus micrantha		*Jasminum sp*
Lagerstroemia flosreginea		*Vitis semicordata*
Populus ciliata		
Prunus persica		
Robinia pseudacacia		
Salix babylonica		
Thuja plicata		

Depending upon the situation, roadside plantations could be in single row or in multiple row. In Haryana and Punjab, in the first row Shisham, Jamun, Mango and Arjun plantations are planted and in the inner rows, a 12 m strip is created of plants like Shisham, *Eucalyptus*, Jamun, Dhak and Mahua. These plantations are made at a spacing of 6 m plant to plant and row to row. Container plants are planted in pits of 50 cm^3 while tall plants (more than 2.5 m) are planted in 60 cm^3 pits. Sowing of kikar in dug-up earth is on heavy soils where a continuous trench of 30 × 30 cm is dug. The seedlings are spaced out in the first year at 4 m apart. For tall plants, spacing is kept at 7.5 m. For aevenue plantation, the distance from the centre of the road is 9 m for highways and 7.5 m for linkroads. Usual nursery practices are followed for raising the nursery which are generally on the roadsides for easy transport of the planting material.

In case of temperate species, like poplars and willows, 7.5 to 10 cm cuttings are put in nursery during November and December. The lower thick end is put in pits of 1 × 1 × 1.5m and covered by soil. The plants are taken out in spring and planted in prepared pits of 45 cm^3 in a single row. The pits are made in previous autumn at a spacing of 2-3 m.

Soil working and methods of propagation

Soil working techniques for roadside plantations for different soils vary. These are largely dependent on species, edaphic conditions and irrigation available. Different techniques have been evolved based on trial. The earth work is carried out for (i) direct seed sowing; (ii) planting of plants raised in containers; (iii) root and shoot (stump) planting and (iv) for planting tall plants for direct sowing. Continuous trench of a section of 30 cm × 30cm is dug in comparatively light soil and seed sowing is done on dug-out earth as well as inside the trench. It is done generally along the boundary of the strips or along the bunds and drains where the earth is relatively loose. In other soils, continuous trench is 60 cm wide and 30 cm deep. Dug-out earth is filled in half of the width of the trench whereby a 20-25 cm high ridge is formed. The seed is sown on this ridge. In wide strips where the ground is fairly level and the soil is compact, soil working on double trench pattern is carried out. In this case, earth of both trenches dug side by side is refilled in one trench to form a ridge for sowing the seed. The other trench is left for storage of rain water. The pits for planting container plants are generally 50 cm in diameter at top and 45 cm deep. The dug out earth is refilled at the time of planting, leaving a 10 cm deep trough unfilled for irrigation. For root and shoot (stump) planting a continuous trench 30 cm × 30 cm section is dug. At the back of the trench, slots 20 cm × 20 cm × 20 cm about 10 cm higher than the bed of the trench are made. The slots are placed 3 cm apart. The stump is planted in the centre of the slot. For tall plants. the pits dug are 80 cm in diam. at the top and 60 cm deep, The dug out earth is refilled at the time of planting except a 15 cm deep trough, left unfilled for holding irrigation water. The soil working is done in advance and the dug out earth is left for weathering till the sowings and plantings are done actually.

Avenue plantations are generally raised artificially. However, regeneration of species such as *Acacia nilotica, Prosopis cineraria* and *Zizyphus mauritiana* that come in strip of species, is taken care of by adjusting the espacement while carrying out planting operations. Sowing is done in case of *Acacia nilotica* while in cases like *Prosopis cineraria*, p. *juliflora*, *Acacia senegal*, *A. nilotica*, *Parkinsonia* sp., planting stock is raised in containers. There are mostly polythene bags, galvanised iron tubes and earthen bricks. The size of plants vary from 80 cm to 1.25 m in height at the time of planting. At places where flow irrigation is practised, root and shoot cuttings of Shisham are planted. Nim (*Azadirachta indica*) is raised in nursery beds and large-sized plants 1.5-2.5 m high are planted with balls of earth. In case of *Dalbergia sissoo* and *Albizia lebbeck* special technique is applied to raise large-sized plants from root and shoot (stump) cuttings. The root and shoot cuttings with 13-15 cm root portion and 2-3 cm shoot portion are planted at a spacing of 45 cm × 45cm in nursery beds, on sprouting healthy shoots are singled out on each stump. All efforts are made whereby plants attain a size of more than 2.5 m by the next planting season in rains. This growth is attained in 6-12 months depending on site conditions. These are extracted with balls of earth when not less than 45 cm high and 25 cm diameter. Tall plantings safeguard against damage by grazing and browsing. While transporting tall plants from nursery to planting site, care is taken of earth balls. On sandy soils, extractors are used to ensure proper size of balls of earth with tall plants and to avoid damage during transport and handling. Method of propagation of some important species is recorded as follows.

Table 3 : Method of propagation of a few species

Species	Method and Time of propagation		Size of planting stock
1	2		3
Acacia nilotica ssp. *indica*	Direct sowing. Row on bunds, drains, boundaries, row canal.	Last week of June	1-1.2 m
	9 months plant, raised in polythene bags, earthen bricks.	July	
Albizia lebbcek	6-12 month plant raised from root and shoot/entire	July	1-1.2 m
Azadirachta indica	1 year old plant, raised from nursery bed	July	1.5 m
Dalbergia sissoo	6-12 months old plant raised from root-shoot cutting/entire plants.	July	2.5 m
Eucalyptus hybrid	6-9 months plant raised in polythene bags, in rows.	July	1.0 m
Parkinsonia aculeata	3-4 months plant, raised in polythene bags, earthen ball.	July	1.0 m
Prosopis cineraria	9 months plant, raised in polythene bags.,	July	0.60 m

Table 4

Species	Habit	Method and time of propagation
1	2	3
Artabotrys odoratissimus	Scandent shrub. Flower hidden in leaves emitting delicate perfume like of over-ripe apples. Fls. July-August.	Seed or cutting. July
Anthocephalus indicus	Leaves glossy. Fls. white	By seed June/July
Carissa carandas	Small thorny shrub. Buds open in evening and emit delicious fragrance.	By seed, July
Cestrum nccturnum	Lady of Night, shrub	By cuttings, July
Citrus aurantium	Spring shrub. Fl. fragrant	By seed, July
Gardenia florida	Delightful shrub; Native of China	By seed, July
Gardenia lucida	Small tree; 2.5-3 m high.	By cuttings, July
Gardenia latifolia	Small tree with long leaves 45×15 cm	By cuttings, July
Gardenia resinifera	Large shrub or small tree. Fls. open in evening and die soon. Wild in Burma.	By seed, July
Hiptage madablota	Rampant shrub with fragrant flowers.	By seed, July
Ixora parviflora	Native of China. Shrub 2-3 m high.	By layers or cuttings, July
Jasminum sambac	Straggling Shrub	By cuttings, July
Lawsonia alba	Egyptian privet. Long spikes of creamy fls. with clinging fragrance.	By cuttings, July

Contd.

1	2	3
Magnolia grandiflora	Small tree 3.5-5 m	Gootee, July
Michelia champaca	Handsome evergreen tree, 5-7 m ft, fls. emit delicious fragrance.	By seed, July
Mimusops elengi	Tree with spreading crown	By cuttings, July
Murraya exotica	Chinese box; English shrub fls. sweet scented.	By seed, July
Nyctanthes arbor-tristis	Tree about 3 m	By seed, quick growing, July
Tabernaemontana coronaria	Shrub 1.3-3m with broad shinging leaves. Flower white only; slightly fragrant.	By layers or cuttings, July

Table : 5 Ornamental flowering trees-colour and time of flowering

Species	Flower colour	Flowering time†
1	2	3
*Acacia auriculaeformis** A. Cunn. ex Benth.	Branches pendulous, phyllodes leaflike, fls. white	At various times of year
Anogeissus pendula Edgew*	Drooping branches	May-June
Amherstia nobilis Wall.	Salmon pink with golden spots	November/April
*Azadirachta indica** A. Juss.	White	March-May
Bauhinia acuminata L.	White	May-Aug
Bauhinia alba Buch.-Ham.	White	April
Bauhinia corymbosa Roxb.	Rosy white	April
Bauhinia purpurea L.	Purple to liliac or red	November
Bauhinia tomentosa L.	Pale yellow	October-November

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*Foliage trees

†Flowing time would vary depending on elematic conditions of a region.

Contd.

1	2	3
Bauhinia triandra Roxb.	Pink	October & November
B. variegata L.	Pink, white purple	Feb.-March
Bignonia crispa Buch.-Ham.	White	May-June
Boulsanthus speciosus Harms.	Deep Blue	March
Brownea coccinea Loefl. ex Griseb.	Scarlet red	March
Brownea ariza Benth	Rose red	March
Brownea grandiceps Jacq.	Bright red	March
Brassica actinophylla F. Muell	Crimson	July
Butea monosperma (Lamk.) Taub.	Scarlet Orange	February-March
Callistemon lanceolatus Sweet*	Scarlet, branches pendulous	March
Cassia fistula L.	Yellow	April-May
Cassia javanica L.	Pink	May-June
Cassia nodosa Buch.-Ham.	Pink	May-June
Cassia renigera Wall.	Pink	May-June
Choriosa superba St. Hill	Light yellow	October
Cochlospermum gossypium DC.	Yellow	February-March
Colvillea racemosa Bojer	Orange to red	July-August/ Oct.
Cordia sebestina L.	Orange to red	January-March
Crataeva religiosa Forst. f.	White	April
Delonix elata (L.) Gamble	Yellow white	Feb.-March
Delonix regia Raf.	Scarlet red	April-June
Dillenia indica L.	White	July
Diospyros embryopteris Pers.*	Leaves smooth, shining	June-August
*Emblica officinalis** Gaertn.	Leaves feathery	March-May
Enterolobium saman Prain	Pale pink	March-Sept.
Erythrina indica Lamk var. *parcelli*	Scarlet red	Feb.-March

Contd.

1	2	3
Erythrina blakei Hort.	Red	April
Erythrina cristagalli L.	Deep red	April
Eucalyptus citriodora Hook*	Trunk slender, clean, leaves lemon scented	Feb.-April also in Nov.
Eucalyptus filicifolius F. Muell*	Crimson	March-Adril
Eugenia cuspidata Berg*	Crown shady, leaves bright, fls. green, stem, light yellow.	March-May
Ficus benghalensis	Fig red	*April-May
Ficus infectoria Roxb*	Copper coloured foliage in April	*April
Ficus retusa L.	Glossy dark green leaves	*Feb.-April
Filicium decipiens Thw.*	Ornamental fern like leaf	March
Gliricidia maculata HB & K.	Pale pink	February-March
Guaiacum officinale L.	Bright Blue	March & November
Hibiscus collinus Roxb.	Rose pink with dark puce coloured eye	November-December
Jacaranda mimosaefolia D. Don	Violet Blue	March-April
Kydia calycina Roxb.	White	September-October
Lagerstroemia flos-reginae Retz.	Mauve purple or Mauve pink	April-May & July-August
Lagerstroemia thorelii Gagnep	White & Mauve	July-September
Lysiduce rhodostegia	Rose-purple	January-February

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*Figs

Contd.

1	2	3
Madhuca latifolia	Calyx plum coloured. Corolla creamy white	February-April
Melia azedarach L.*	Bark smooth, leaves beautiful.	March-May
Mesua ferrea L.	White	April-May
Milletia ovalifolia Kurz	Liliac	March
Millingtonia hortensis L.	Silvery white Fls. fragrant	April-June and November-December
Moringa pteryosperma Lamk. et Gaertn.	Creamy white	February-April
Mussaenda glabra	Orange	July-October
Ochna squarrosa L.	Bright yellow, blue	May
Oncoba spinosa Forsk.	White	April-May
Peltophorum ferrugineum Benth.	Bright Yellow	March-May and September to November
Pterocarpus indicus Willd.	Golden yellow	May-July
Pterocarpus echinatus Pers.	Or. yellow	April-May
Pterocarpus indicus Willd	Yellow	March-April
Plumeria acutifolia Poir.	White	March-April
Plumeria alba L.	White	March-April, & July-October
Plumeria rubra L.	Red	March-April, & July-October
Polyalthia longifolia Benth. et Hook. f.*	Yellowish Green	Feb.-May
Pongamia glabra Vent.	Mauve	April-May
Putranjiva roxburghii Wall.*	Dense glossy foliage on pendulous branches	April-May June-August
**Sapium sebiferum* Roxb*	Leaves turn, bright scarlet in	
Saraca declinata Miq.	Or. yellow	Feb.-March

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*Leaves start changing colour in Jan. Leafless Feb.-April.

Contd.

1	2	3
Saraca indica L.	Orange. Red	February-March
Schizolobium excelsum Vog.	Bright yellow	February-March
Sesbania grandiflora Poir.	Cream or pink	December
Solanum grandiflorum Ruiz et Paven	Blush violet	All year
Spathodea campanulata Beauv.	Orange crimson	February-March
Spathodea nitotica Seem.	Orange yellow	February-March
Sterculia foetida L.	Crimson	February-March
Stenocarpus sinuatus Enal	Scarlet	May-June
Syzygium eumini (L.) Skeels	Greenish	March.May
Tamarindus indica L.*	Crown large spreading	May-June
Tabebina rosea DC.	Pale mauve	June
Tecomella undulata Seem	Orange yellow	March-April
Terminalia arjuna Bedd.	Creamy, cup shaped	March-June
Thespesia populnea Soland ex Correa	Yellow and cinnamon red	All year round
Wrightia tinctoria R. Br.	Red	May

*Foliage trees

2. Community Centres for recreational activities and meetings

Such places in the rural as well as urban setting need be planted with shady and/or ornamental species. The common species for such locations usually planted are Pipal (*Ficus religiosa*), Bargad (*F. benghalensis*), Imli (*Tamarindus indica*), Neem (*Azadirachta indica*) and Siris (*Albizia lebbek*). Existing trees of *Tamarindus indica* in the arid areas have eroneously led to believe the climate of the area as humid though these were planted near village sites which have now been abandoned. *Adenanthera pavonia*, *Samanea saman* and *Peltophorum ferrugineum* are some of the favoured species in peninsular India. Some of the other less favoured species are Mahua (*Madhuca indica*),

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*Tabuvia argentea with yellow flowers is successfully grown in Jodhpur.

Khirni (*Mimnsops hexandra)*, Arjun (*Terminalia arjuna)*, Bahera (*T. bellirica)* and Kathal (*Artocarpus lakoocha)*. However, *Azadirachta indica*, *Albizia lebbek* and *Tamarindus indica* are some of the most common species preferred on these sites. In arid area, *Parkinsonia aculeata*, *Prosopis cineraria*, *P. juliflora* are most common near the water source. Flowering and foliage shrubs are recorded below which may be planted in addition to various shade and ornamental species given in the table.

A. *Schools and rest house gardens*

Flowering and foliage shrubs
Lagerstroemia indica
Tabernaemontana coronaria
Palms
Crotons
Pisonia alba
Arundo donax
Hibiscus (different varieties)
Amomum magnificum
Poinsettia pulcherrima
Heliconia aurestriata
Panax fruticosum
Aralia filicifolia
Mussaenda erythrophylla
Gardenia florida
Plumeria rubra
Annona squamosa

Climbers
Solanum wendlandii
Allamanda hendersoni
Bignonia venusta
Antigonon leptopus
Clerodendrum thomsonae
Petrea volubilis
Congea tomentosa
Ipomoea briggsii
Solanum seaforthianum

B. *Memorial places*—These are sometimes selected from the list of trees and shrubs given in table below. However, association of some plants like *Aloe veera* in cemetries of Rajasthan, *Iris* in Jammu and Kashmir is worth mention. Among the tree species, *Cupressus torulosa*, *Salix babylonica* have been observed in hilly region while in plains, shade and fruit bearing trees like Mango, Guava are preferred.

Trees—Flowering
Amherstia nobilis
Brownea grandiceps
B. macrophylla

Foliage trees
Agathia robusta
Araucaria bidwillii
A. excelsa

Cassia grandis
C. nodosa
Couropita guianensis
Jacaranda mimosaefolia
Lagerstroemia flosreginae
Mesua ferea
Peltophorum ferrugineum
Plumeria rubra
Delonix regia
Schizolobium excelsum
Spathodea campanulata
Cassia fistula
Millingtonia hortensis
P*lumeria acutifolia*
P. *rubra.*

Artocarpus incisa
Bertholletia excelsa
Chrysophyllum cainito
Enterolobium cyclocarpum
Fagraea fragrans
Ficus benjamina
Parkia roxburghii
Podocarpus cupressinus
Pterocarpus indicus
Swintonia mahagoni
Grevillea robusta
Stenocarpus sinuatus
Syncarpia laurifolia
P*olyalthia longifolia*
Tamarindus indica

C. *Temples*—Worship of certain trees, supposed to be possessed of spirits has at all times been practised in many parts of the world. The custom still survives amongst many races and religions in various countries. In India and Africa, there are many such trees and are regarded as objects of veneration or esteemed as examples of some special virtue. Coconut palm *(Cocos nucifera)* is venerated in some countries, an emblem of fertility and is widely used in offerings. Throughout the temples in peninsular and coastal states of the country this tree is planted near the temples. Varieties of the oil palm and other trees are said to be possessed of soul or spirit of ancestors, e.g. *Adansonia digitata* (Baoboab tree) of Central Africa. Sacred trees are not always chosen as such for their utility. Shrines for the offering of prayers with flowers are commonly erected under such trees like *Ficus religiosa, F. benghalensis,* etc. Leaves of *Aegle marmelos* (Bilva) are offered to Lord Shiva during the months of July/August. Similarly, *Emblica officinal* is (Amla) is considered sacred and planted near the temples. P*rosopis cineraria* is considered sacred by local people in arid Rajasthan (particularly by Vishnois) and is planted near houses and temples. Offerings of flowers in temples usually consist of sweet-scented flowers as those of P*lumeria, Hibiscus, Tabernaemontana, Nelumbium speciosum,* *Nyctanthes arbortristis.* In the Himalayas, leaves of plants like *Skimmia laureola* and *Juniperus* are sometimes used as incense in the temples. The common Dhoop plant* is used for making Dhoop†. In addition, fragrant leaves such as sacred Basil (*Ocimum sanctum*) is used in the temples. In some of the temples situated at elevations, *Artemisia sacrorum* (Ganga Tulsi) is used extensively while flowers of *Saussurea obovallata* (Vern. Braham-kamal) are offered in the temples and considered effective to wardoff effects of evil spirits.

Some of the common trees and shrubs suitable for temples are as below—

Ficus religiosa (Pipal)
F. benghalensis (Bargad)
Bombax ceiba (Semal)
Kigelia pinnata
Azadirachta indica (Neem)
Naudia domestica
Nauclea cadamba (Kadam)
Nyctanthes arbortristis (Harsingar)
Emblica officinalis (Amla)
Plumeria acutifolia
Prosopis cineraria (Khejri)
Sterculia colorata
Stereospermum xylocarpum
Aegle marmelos
Skimmia laureola

3. *Canal bunds*—These are not put to any productive use and in view of the prevailing demands for forest produce such strips assume great importance. This will add to the availability of fuel wood and small timber. The common species used for planting such sites are *Dalbergia sissoo*, *Eucalyptus hybrid*, *Albizia lebbek*, *Azadirachta indica*, *Acacia nilotica* ssp. *indica* and *A. auriculaeformis.* The plantations are not made on the slope or the outer birm of the bund. The usual practice is to plant species 6 m away from the inner birm of the bund. The techniques used by the Haryana Forest Department consists of line sowing of *Acacia nitotica* ssp. *indica* in dug up earth on banks of feeder canals with loamy soils having patches of clay loam. Where the soil is hard, a continuous trench of 30 cm × 30 cm is dug for *kikar* sowing and the seedlings are spaced out 4 m in the 1st year. Container plants of *kikar* and *Acacia tortilis* are planted in pits of 50 cm^3. Tall plants of *Albizia lebbek*, *Melia azadirach*, *Dalbergia sissoo*

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*Jurinea macroeephala †An ineense

are planted in pits of 60 cm^3, in patches at a spacing of 7.5 m. *Parkinsonia aculeata* is planted on road crossings in order to break monotony. 2-3 spot irrigations from the canal are sufficient, while for tall plants, 4-5 irrigations are needed. Two weedings and hoeings done in *kikar* and *Parkinsonia* during the first year, while for tall plantations, 3-4 weedings are needed. Sometimes, *Saccharum* tufts are also planted in patches of 25×25 cm by digging the site 15 cm deep. No serious damages to plantations have been recorded except by cattle and camel. Kikar roots are sometimes nibbled by rats and cause considerable damage. Cost of such plantations have been estimated at Rs. 400/- per running km. In western Himalayas plantations of *Alnus nepalensis Betula anoides, Ulmus wallichiana* and *Robnia pseudacacia* are successful.

4. *Railway lines and station yards*—The sides of the railway tracts offer potential sites for tree plantation programme. Since these fall under diverse geoclimatic zones, selection of species and soil working will depend on site characters. Potential species for different sites are the same as for roadside plantation programme. Various divisions of the Railway administration need be involved and local staff may be given short-term training for planting and saving trees. Nurseries need be established at site for the implementation of this programme.

Strip forests along railway lines and station yards, have been planted by the Haryana Forest Department. *Acacia tortilis* and *Parkinsonia aculeata* are planted in pits of 45 cm^3 at 3 m×3 m spacing for container plants. Both these species are raised in polythene bags of 30 cm×20 cm size (150 gauge) by sowing 2-3 seeds in each bag during February-March. Polythene bags having plants of 30-50 cm height are planted after opening the bottom of these bags. Three spot irrigations at the rate of 15 lit. of water per plant are provided. 2-3 weedings and hoeings are done around the plants to the extent of 0.5 m on all sides during the first year of the establishment. The cost of such plantations is recorded at Rs. 550/- per ha.

Apart from their bio-aesthetic consideration, plants selected for such sites should have shade bearing and ornamental effects apart from being utilised for fuel, fodder and development of some agro-industries. Some of the common species are *Acacia nilotica* ssp. *indica*, *Tamarindus indica*, *Dalbergia sissoo*, *Morus indica*, *Pongamia glabra*, *Mangifera indica*, *Azadirachta indica* and *Ficus* sp. Apart from the tree species, plants like *Agave* sp., *Vitex negundo*, *Saccharum munja*, *Ipomea carnea* and other grasses stabilise the soils near the railway tract which are often subjected to wind and water erosion, thus creating traffic hazards. Areas susceptible to wind erosion are protected by planting shelterbelts along the railway lines so that the uplifting of finer soil particles and deposition on railway tracts is reduced. Planting of grasses by creating microwind breaks through mulching is the common practice along roads and railways in regions of Bikaner Division. The operations are almost similar to sand dune fixation works described elsewhere in this note.

5. *Rural and urban homes*—The village homes are generally planted with native species like Sonjna (*Moringa pterygosperma*), Jamum (*Syzygium cumini*), Lasora (*Cordia myxa*), Ber (*Zizyphus mauritiana*), Karonda (*Carissa spinarum*), Nim (*Azadirachta indica)*, Imli (*Tamarindus indica*), Mahua and many other species of plants meant for shade and fruits. In urban homes, the plants are grown mostly for flowers and fruits. For the rural society in the hills, the plants near the homes provide valuable fodder for the bovine population and some of the most favoured species include Oaks, *Bauhinias*, *Grewias*, *Celtis*, etc. In Kashmir valley, plantations on the rural sites include mostly *Salix* (*S. alba*, *S. babylonica*). Poplars and *Robinia pseud-acacia* which are exploited for their branches and top feed leaf fodder.

For urban homes ornamental trees and shrubs can be classified according to the places where they are to be useful and also according to the habit. Trees and shrubs may be flowering, evergreen or deciduous. Tall and shady trees generally mar the view of the buildings. Similarly trees with spreading root system such as *Bauhinia* sp., *Alstonia scholaris*, *Barringtonia acutangula*, *Heritiera*, *Putranjiva*, *Artocarpus*, *Terminalia arjuna*, *Cedrela toona*, *Albizia* and *Dalbergia sissoo*, *Ficus reli-*

giosa and *F. bengalensis* are not preferred since they damage the foundation of the buildings. Even epiphytic plants like pipal and Bargad which sometimes come naturally are removed regularly from the house walls since they damage the walls and the foundation as they grow.

The plants protect the building, serving as wind breaks or in amelioration of climatic conditions. The change of colour of leaves, leaffall and leaf bud opening are some of the phenomena which can impart a great variety of colour and scenic beauty. Flowers give a bio-aesthetic satisfaction to people since they attract birds and other small animal life which enliven scenery around the dwellings.

Tall ornamental flowering trees suitable for urban homes are *Acacia dealbata*, *Amherstia nobilis*, *Bauhinia purpurea*, *B. variegata*, *Bombax ceiba*, *Brownea grandiceps*, *Butea monosperma*, *Callistemon lanceolatus*, *Camellia japonica*, *Cassia fistula*, *C. grandis*, *C. javanica*, *C. marginata*, *Cochlospermum gossypium*, *Couropita guianensis*, *Erythrina indica*, *Jacaranda mimosaefolia*, *Kigelia pinnata*, *Lagerstroemia speciosa*, *Magnolia grandiflora*, *M. campbelli*, *Mesua ferrea*, *Michelia champaca*, *Millingtonia hortensis*, *Plumeria acutifolia*, *P. rubra*, *Delonix regia*, *Rhododendron arboreum*, *Saraca indica*, *Spathodea campanulata*, *Sterculia colorata*, and *Thespesia populnea*.

Foliage trees suitable for urban housing landscape are—*Agathis australis*, *Ailanthes excelsa*, *Alstonia scholaris*, *Acaucaria cooki*, *A. cunninghamii*, *A. excelsa*, *A. bidwilli*, *Casuarina equisetifolia*, *Cupressus funebris*, *Grevillea robusta*, *Melia azadirach*, *Polyalthia longifolia*, *Putranjiva roxburghii* and *Ravanala madagascariensis*.

Among the various palms used are *Areca alba*, *A. lutescens*, *A. triandra Arenga*, *sacchafers*, *Caryota urens*, *C. australis*, *Hyophoebe americaulis*, *H. verschaffeltii*, *Licuala grandis*, *Pritehardia pacifica*, *Oreodoxa regia*, *O. oleracea*, *Martinezia erosa*, *M. caryotaefolia*, *M. truncata*, *Phoenix roeblinii*, *Raphis flabelliformis* and *R. humilis*.

Flowering shrubs generally recommended are—*Bauhinia galpinii*, *Beloperone oblongata*, *Caesalpinia pulcherrima*, *Cestrum nocturnum*, *Clerodendrum fragrans*, *C. kaempfere*, *C. fallax*, *C. phlomoides*, *C. paniculatum*, *C. thomsonia*, *Daedalacanthus*, *Hibiscus mutibilis*, *H. rosa-sinensis*, *Holmskioldia sanguinea*, *Ixora coccinea*, *I. parviflora*, *I. rosea*, *I. chinensis*, *I. undulata*, *I. lutea*, *Lagerstroe-*

mia indica, *Mussaenda erythrophylla*, *Nyctanthes arbor-tristis*, *Poinsettia pulcherrima*, *Tabernaemontana coronaria*. Among the foliage shrubs the most commonly used are *Acalypha hamiltoniana*, *A. godseffiana*, *Aralia filicifolia*, *A. sieboldi*, *Codiaeium croton*, *Cycas circinalis*, *Dracaena reflexa*, *Muchlenbeckia platyclados*, *Pandanus sanderi*, *Agave* sp., *Senseviera zeylanica*, *S. cylindrica* and *Yucca gloriosa*.

Some of the climbers generally favoured are *Aganosma caryophylata*, *Allmanda cathartica*, *Antigonon leptopus*, *A. violacea*, *Aristolochia elegans*, *Asparagus racemosus*, *Beaumontia grandiflora*, *Begnonia magnifica*, *B. unguscati*, *B. venusta*, *Bougainvillea spectabilis*, *Clematis paniculata*, *Chenomorpha macrophylla* and *Jacquomontia violacea*, *Hiptage madablota*, *Jasminum grandiflorum*, *J. auriculatum*, *Passiflora racemosa*, *Petrea volubilis*, *Thunbergia fragrans*, *Vallaris heynei*, *Rhynchospermum jasminoides*, *Clerodendrum inerme*, *Clitorea ternatea*, *Solanum jasminoides*, *Ipomoea bonanox*, and *I. sinuata* etc.

A number of plants suggested for house fronts are given as below—

Trees for house fronts :

Salix babylonica
Thevetia nerrifolia
Bauhinia monandria
Bigonia crispa
Callicarpa americana
Cassia multijuga
Magnolia grandiflora
Plumeria rubra
Saraca declinata
Araucaria cookii
Cupressus funebris
Ficus elastica
Ravanala madagascariensis
Thuja orientalis var. *compacta*
Areca lutescens
Caryota urens
Kentia belmoreana
Millingtonia hortensis
Tecoma stans
Acacia farnesiana
Alstonia scholaris
Albizia lebbek
Anthocephalus cadamba
Michelia champaca
Mimusops elengi
Parkinsonia aculeata
Pterospermum acerifolium

Trees suitable for housebacks :

Achras sapota
Averrhoea carambola
Persea americana
Emblica officinalis

Carica papaya
Citrus nobilis
C. sinensis
Cyphomandra betacea
Malpigia glabra
Ficus carica
Mangifera indica
Psidium guajava
Prunus domesticus
P. persica
Punica granatum
Pyrus communis
Annona squamosa
Nephlium litchi

The literature available on landscaping gives details regarding the flowering time, colour of flowers and habit of each plant species (Pal 1960, Randhawa 1957). However, propagation methods, foliage, flowering, leaffall and popular names ofsome of the important species are given in tables 3,5 & 6.

Shrubs and climbers for houses :

Artabotrys odoratissima
Buddleja asiatica
Brunfelsia americana
Carissa carandas
Cestrum nocturnum
Clerodendrun fragrans
Dombeya sp.
Gardenia sp.
Hamiltonia suaveolens
Jasminum sp.
Lawsonia alba
Murraya exotica
Myrtus communis
Nerium indicum
Nyctanthes arbortristis
Oncoba spinosa
Porana paniculata
P. racemosa
Aganosma caryophyllata
Asparagus racemosa
Clematis paniculata
Hipage madablota
Jasminum grandiflorum
J. auriculatum
Lonicera japonica
Passiflora racemosa
Rhynchospermum jasminoides
Antigonon leptopus
Bougainvillea sp.
Solanum jasminoides
Thunbergia fragrans
Clerodendron incerne
Clitorea ternatea-alba
Ipomoea bonanox
I. sinuata

Dwarf ornamental trees suitable for small compounds :

Flowering trees—*Acacia auriculaeformis*, *Alangium lamarckii*, *Bauhinia purpurea*, *B. variegata*, *Butea monosperma*, *Cassia fistula*, *C. javanica*, *C. marginata*, *Cochlospermum gossypium*, *Cordia sebestina*, *Crataeva religiosa*, *Erythrina blakeii*, *E. cristagalli*, *Guaiacum officinale*, *Gliricidia maculata*, *Holarrhena antidysenterica*, *Jacaranda mimosaefolia*, *Brownea coccinea*, *B. ariza*, *Kleinhovia hospita*, *Lager-*

stroemia thorelli, Mesua ferea, Milletia auriculata, Pongamia glabra, Plumeria rubra, P. alba, Solanum wrightii, Spathodea nilotica, Sterculia colorata, Tecomella undulata and Thespesia populnea.

Fragrant trees and shrubs :

Alstonia scholaris
Anthocephalus indicus
Artabotrys odoratissimus
Gardenia lucida
G. latifolia
G. florida
Heptage madablota
Ixora parviflora
Lawsonia alba
Magnolia grandiflora
Michelia champaca
Murraya exotica
Nyctanthes arbor-tristis
Schinus molle

Foliage trees :

Averrhoa carambola
Callistemon lanceolatus
Citharexylum subserratum
Polyalthia longifolia

Oranmental fruit trees :
Hazara Orange.

Trees suitable for big compounds :

Flowering trees :

Anthocephalus indicus
Cassia nodosa
C. grandis
Choriosa speciosa
Colvillea ramosa
Lagerstroemia flos-reginae
Bombax ceiba
Millingtonia hortensis
Peltophorum ferrugineum
Delonix regia
Sterculia colorata

Fragrant trees :

Dillenia indica
Pterospermum acerifolium
Mimusops hexandra

Ornamental foliage trees :

Eucalyptus species
Emblica officinalis
Putranjiva roxburghii
Terminalia arjuna

Shade Trees :

Diospyros embryopteris
Kiegelia pinnata
Tamarindus indica
Ficus retusa
F. infectoria

Some of the trees like *Bauhinia purpurea*, *B. variegata*, *Callistemon lanceolatus*, *Aesculus indica*, *Syzygium cumini*, *Azadirachta indica*, *Dalbergia sissoo*, *Sapindus mukrosii*, *Toona ciliata* and *Crataeva religiosa* yield nectar and may be suitable for apiary.

Plants for rockeries and fern houses : Though this is outside the scope of this note, plants of rockeries and fern houses are common in elite urban homes. For rockeries, various oreophytes such as *Sensevieras*, *Agave*, *Opuntias*, *Cereus* species are planted with many ferns like *Adiantum*, *Asplenium*, *Pteris*, *Polypodium*, *Nephrodiums*, etc. The common ferns that are mostly used in houses are given in appendix :

Plants for hedges and boundaries :

a) Ornamental and screen (For low elevations)

Acalypha marginata
Aralia filicifolia
A. guilfoylei
Bambusa nana
Barleria cristata
Brunfelsia uniflora
Casuarina equisetifolia
Croton (*Codiaeum*)
Duranta plumieri
Hibiscus rosa-sinensis
Justicia gendarussa
Malpighia glabra
Murraya exotica
Panax fruticosum
Phyllanthus myrtifolius
Pithecolobium dulce
Punica granatum
Ehretia buxifolia

(For upcountry)

Berberis aristata
B. fortunei
Caesalpinia sepiaria
Cestrum fasciculatum
Cryptomeria japonica
Furcraea gigantea
Cupressus macrocarpa
Ligustrum ovalifolium
Lonicera nitida
Reinwardtia trigyna
Spiraea peruviana
Tecoma capensis
Ulex europea

b) Boundaries .

Acacia tortuosa
A. modesta
Agave americana
Balsamodendron berryi
Bougainvillea spectabilis
Caesalpinia sappan
Capparis zeylanica
Flacourtia indica
Haematoxylon campechianum
Jatropha curcas
Lawsonia alba
Lantana camara
Maytenus emarginata
Pandanus zeylanicus

Carissa spinarum
Citrus decumana
Clerodendrum aculeatum
Dichrostachys cinerea
Dodonaea viscosa
Euphorbia antiquorum
E. caducifolia
Parkinsonia aculeata
Pithecolobium dulce
Pithecolobium angustati
Tecoma capensis
Triphasia trifoliata
Zizyphus spina-cristi.

c) Edgings for paths and borders :

Alternanthera sp.
Amaryllis sp.
Anthericum liliastrum
A. variegatum
Buxus semepervirens
Caladium humboldii
Caralluma campanulata
Cyrthanthus mackenii
Malphigia coccigera
Ophiopogon intermedius
Phalaris arundinacea
Phyllanthus myrtifolius
Pilea muscosa
Pyrethrum aureum
Stapelia grandiflora
Santolina chaecyparissu
Telanthera sp.
Zephyranthes carinata
Z. tubispatha.

Cassia auriculata has been successfully tried in arid and semi-arid zones for hedge. Other plants used for hedge boundries in the region are *Dodonhea viscosa*, *Parkinsonia aculeata*, *Inga dulcis*, *Euphorbia nerrifolia*, *Calligonum polygonoides*, *Clerodendrum phlomoides*, *Maytenus emarginatus*, *Salvodora persica* and *Tamarix articulata*. *prosopis juliflora* has been used in some places but not liked because of thorns.

Table . 6 *Classification of ornamental trees according to size, indicating height, crown spread, growth rate, foliage and spread of root system. (Adapted from Randhawa 1957).*

A. *Deciduous—Large sized*

Tree species	Height (ft.)	Spread	Growth	Foliage	Root structure
1	2	3	4	5	6
Ailanthes excelsa	40-50	Tall	Quick	Light	Large
Bombax ceiba	40-60	Tall	Quick	Light	Large

Contd.

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1 ft = 30 cm approv.

Chorisia speciosa	30-35	Medium	Quick	Light	Large
Ficus infectoria	35-50	Wide spread	Quick	Thick	Large
Millingtonia hortensis	50-60	Tall & small spread	Quick	Light	Large
Albizzia procera	60-80	Tall & good spread	Quick	Light	Medium
		Medium-sized trees			
Bassia latifolia	30-40	Compact	Very slow	Thick	Medium
Bignonia crispa	25-30	Compact	Slow	Light	Medium
Cassia javanica	25-30	Spreading low crown		Light	Medium
Cassia nodosa	20-30	Spreading low crown		Light	Medium
Delonix regia	25-35	Large spread	Quick	Light	Medium
Erythrina indica	25-35	Medium	Quick	Light	Medium
Lagerstroemia flos-reginae	20-30	Medium	Quick	Light	Medium
Peltophorum inerme	20-35	Spreading	Quick	Thick	Medium
Schleichera trijuga	30-40	Spreading	Quick	Thick	Medium
		Small-sized trees			
Bauhinia acuminata	20-30	Medium	Quick	Light	Small
Bauhinia variegata	20-30	Medium	Quick	Light	Small
Bauhinia triandra	20-30	Medium	Quick	Light	Small
Butea frondosa	20-35	Irregular	Slow	Thick	Small
Cassia renigera	15-20	Medium	Quick	Light	Small
Cassia fistula	25-35	Medium	Quick	Light	Small
Crataeva religiosa	25-30	Small	Slow	Light	Small
Erythrina suberosa	40-50	Small	Quick	Light	Small
Jacaranda mimosaefolia	25-35	Medium	Quick	Light	Small
Milletia ovalifolia	20-25	Small	Slow	Light	Small
Spathodea campanulata	25-35	Small	Quick	Light	Small

1	2	3	4	5	6
B.	*Evergreen*	*Trees—Large-sized*			
Colvillea racemssa	40-50	Spreading crown	Quick	Light	Large
Enterolobium saman	60-80	-do-	Quick	Light	Large
Ficus retusa	50-60	-do-	Slow	Thick	Large
Polyalthia longifolia	40-50	Tall with downward branches	Quick	Light	Large
Pterospermum acerifolium	40-50	Tall with spinney branch	Slow	Light	Large
Sterculia alata	30-45	Medium	Quick	Light	Small
		Mcdium-sized			
Azadirachta indica	30-40	Medium	Quick	Light	Medium
Casuarina equisetifolia	35-45	Ornamental crown	Quick	Thick	Medium
Cedrela toona	40-50	Medium	Quick	Light	Medium
Syzygium cumini	30-40	Dense crown	Quick	Thick	Medium
Syzygium fruticosa	30-40	Dense crown	Quick	Thick	Medium
Grevillea robusta	30-80	Columnar	Slow	Thick	Medium
Kigelia pinnata	5-45	Medium	Slow	Thick	Medium
Tamarindus indica	35-40	Spreading	Very slow	Light	Medium
		Small trees			
Acacio auriculaeformis	30-40	Columnar	Medium	Light	Small
Acacia moniliformis	20-30	Columnar	Very slow	Light	Small
Calophyllum inophyllum	20-25	Columnar	Very slow	Thick	Small
Cassia siamea	25-35	Medium	Very slow	Thick	Small
Diospyros embryopteris	25-30	Spreading	Very slow	Thick	Small

Contd.

1	2	3	4	5	6
Dillenia indica	30-40	Spreading	Very slow	Thick	Small
Guiacum officinale	30-40	Rounded	Slow	Thick	Small
Lagerstroemia thorelli	20-25	Medium	Quick	Light	Small
Mesua ferrea	20-25	Medium globose	Quick	Light	Small
Putranjiva roxburghii	25-30	Columnar slight spreading	Slow	Thick	Small
Plumeria alba	20	Low spreading	Slow	Thick	Small
Plumeria acutifolia	20	-do-	Slow	Thick	Small
Emblica officinalis	25-30	Medium	Quick	Thick	Small
Thespesia populnea	25-30	Umbrella like	Quick	Thick	Small
		Palms			
Borassus flabellifer	40-60	Erect unbranched	Slow		Small
Cocos nucifera	80-90	-do-	Slow		Small
Livistonia chinensis	60-80	-do-	Slow		Small
Oreodoxa regia	50-60	-do-	Slow		Small
Phoenix dactylifera	30-40	-do-	Slow		Small

Table 7. *Ornamental shrubs and their important characteristics*

Name 1	Colour of flowers 2	Method of Propagation 3	Time of flowering 4
Acalypha hispida	Deep red	Cuttings/seeds	Autumn
A. wilkesiana	Foliage coloured	-do-	-do-
Allamanda cathartica	Bright yellow	Cuttings/ layers	Hot
A. cathartica var. *nobilis*	Yellow	-do-	Rainy
var. *schortii*	Yellow with dark streaks	-do-	-do-

1	2	3	4
A. neriifolia	Yellow with Orange streaks	-do-	Hot
Aphelandra fascinator	Scarlet	Cuttings	Autumn
A. fulgens	Bright scarlet	-do-	Winter
A. tetragona	-do-	-do-	Hot
Artabotrys uncinatus	Pale yellow	Seed/layers/ cuttings	Rainy
Asclepias curassvica	Red and Orange	Seeds	Winter
Azalea spp.	Variations of brick red, crimson, bright yellow, orange blotch cream, yellow apricot, pink and white.	Seeds/layers/ graft/ cuttings	Rainy
Barleria cristata	Purplish blue	Cuttings	Spring
B. gibsonii	Blue	-do-	Winter
B. lupulina	Yellow	-do-	Spring
B. tomentosa	Rose	-do-	-do-
Bauhinia acuminata	Snow white	-do-	Hot
B. galpinii	Brick red/ crimson	-do-	Autumn
B. tomentosa	Sulphur yellow	-do-	-do-
Beloperone guttata	White	-do-	-do-
Bougainvillea buttiana	Shades of white orange, pink, scarlet, crimson and purple.	-do-/ layers	Several flushes
B. glabra	-do-	Cuttings/layers	Several flushes
B. peruviana	-do-	-do-	-do-
B. spectabilis	-do-	-do-	-do-
Brunfelsia americana	White, turning yellow	-do-	-do-

Contd.

1	2	3	3
Buddelia asiatica	White	Cuttings/seeds	Winter
B. davidii	Liliac purple with a touch of orange yellow at mouth	-do-	Rainy
B. lendleyana	Purplish violet	Seeds/Cuttings	-do-
B. madagascariensis	Orange Yellow	-do-	Hot, Autumn
Calliandra brevipes	Bright pink	Seeds/Cuttings/ layers	Winter
C. haematocephala	Bright crimson	Seeds/Cuttings	Winter
Camellia japonica	White to deep crimson	Seeds/Cuttings/ layers/buds	Winter
C. sasangua	White	Seeds/Cuttings/ layers/buds	Spring
Caryopteris incana	Blue, pink, White	Seeds/Cuttings	Spring
Cassia artemisioides	Yellow	Seeds	Winter
Catesbaea spinosa	Creamy white	Layers/cuttings	Raing
Cestrum aurantiacum	Bright Orange	Cuttings	Hot
C. diurnum	Purplish red	Cuttings	Autumn, Winter
C. parquii	Yellow	Seeds/Cuttings	Autumn
Clerodendrum fragrans	Rose	Cuttings	Hot
Clerodendrum indicum	White	Cuttings	Hot
C. squamatum	Deep scarlet	Seeds	Hot
C. cigandense	Blue	Cuttings	Spring
Congea tomentosa	Pink	Seeds/Cuttings	Spring
Crossandra infundibuliformis	Orange, Salmon Pink, red	-do-	Hot, Autumn
Cytissus multiflorus	White	Seeds/Cuttings	Hot
C. scoparius	Bright yellow	-do-	-do-
var. *albus*	Yellowish white	-do-	-do-

1	2	3	4
var. *andreanus*	Yellow with dark crimson wing	Seeds/Cuttings	-do-
var. *pendulus*	Yellow	-do-	-do-
Datura suaveolens	Snow white	Seeds/Cuttings	Spring
Deutzia corymbosa	White	Cuttings	Hot
D. grandiflora	White	Cuttings	Spring, Hot
D. parviflara	White	Cuttings	Hot
D. reflexa	White	Cuttings/Seeds	Hot
Dombeya acutangula	Red	Cuttings/layers	Winter
D. mastersii	White with rosy tinge	Cuttings/layers	Winter
D. spectabilis	White	Cuttings/layers	Winter
Duranta repens	Lavender blue, white	Seeds/Cuttings	Hot, rainy
Eranthemum nervosum	Blue	Cuttings	Winter
Erythrina blakii	Scarlet	Cuttings	Spring
E. indica	Scarlet	Cuttings	Winter
Euphorbia fulgens	Scarlet	Cuttings	Winter
E. pulcherrima	Scarlet with crimson red bracts	Cuttings	Winter
Forsythia sp.	Yellow	Cuttings/seeds/layers	Spring
Fuchsia magellanica	Violet	Cuttings	Spring
Galphimia gracilis	Golden	Seeds	Autumn
Gardenia jasminoides	Creamy white	Cuttings	Hot
Graptophyllum pictum	Crimson	Cuttings	Several flushes
Hamelia patens	Orange red	Seeds/Cuttings	Hot, rainy
Hamiltonia suaveolens	White, mauve	Cuttings	Winter
Hibiscus mutabilis	Variable	Cuttings/layers	Hot
H. rosa-sinensis	Rose pink	Cuttings/layers	Hot

Contd.

1	2	3	4
H. schizopetalus	Light scarlet	Cuttings/layers	Hot
H. syriacus	Liliac blue with purple eye.	-do-	Hot, rainy
Heptage benghalensis	Yellow & White	Seeds/layers	Winter
Holmskioldia sanguinea	Reddish brown	Cuttings/layers	Winter
Hydrangea hortensia	Pink or blue	Cuttings	Hot, Rainy
H. macrophylla	Pink or blue	Cuttings	Rainy
H. paniculata	White/yellow white	Cuttings	Rainy
var. *grandiflora*	White	Cuttings	Rainy
Hypericum hookerianum	Golden yellow	Seeds/Cuttings	-do-
H. mysorensis	Yellow	Seeds	Hot
Ipomoea carnea	Pink, mauve	Cuttings	Flushes
Ixora arborea	White	Cuttings/ layers	Spring
I. chinensis	Pink	Layers	Flushes
I. coccinea	Scarlet	Cuttings/ Layers	Flushes
I. fulgens	Orange scarlet, Scarlet	Cuttings/ Layers	Flushes
I. singaporensis	Orange scarlet	Cuttings/ Layers	Flushes
Jacobinia carnea	Rose purple	Cuttings	Winter
J. coccinea	Scarlet	Cuttings	Winter
Jasminum humile	Bright yellow	Cuttings/ Layers	Hot
J. mesnyi	Bright yellow	Cuttings/Layer	Hot
J. multiflorum	White	-do-	Flushes
J. sambac	White	-do-	Hot
Jatropha hastata	Deep pink	Seeds/ Cuttings	Flushes
J. multifida	Scarlet	Seeds/ Cuttings/Layer	Rainy
J. podaganea	Scarlet	Divisions	Rainy

1	2	3	4
Kerria japonica	Yellow	Cuttings/Lay.	Spring
Lagerstroemia indica	Rose pink, mauve	Cuttings	Hot, Rainy
Lantana camara	White, Yellow, Orange	Cuttings	Rainy
Lawsonia inermis	White rose	Seeds/Cuttings	Winter
Malpigea glabra	Rose red	Cuttings	Hot, Aut.
Malvaviscus arboreus	Bright red	Cuttings	Hot
Memecylon edule	Deep Blue	Seeds/Layers/ Cuttings	Hot
Montanoa bippinatifia	White, yellow	Cuttings	Winter
Murraya paniculata	White	Cuttings	Flushes
Mussaenda frondosa	Yellow	Cuttings	Rainy
M. macrophylla	White, yellow, crimson	Cuttings	Raing
M. philippiea	White, deep rose, red	Cuttings	Rainy
Myrtus communis	White	Seeds/layers/ cuttings	Winter
Nerium indicum	White cream, pink deep red	Cutttngs/layers	Flushes
Cultivar Dr. Golfin	Deep cerise	Cuttings/layers	Hot
Ochna squarrosa	Yellow	Cuttings	Hot
Oncaba spinosa	White	Cuttings	Hot
Osmanthus fragrans	White, yellow	Cuttings	White
Paeonia albiflora	White	Divisions	Hot
P. lactiflora	White	-do-	Hot
P. officinalis	Red	Grafts/layers	Hot
P. suffruticosa	White, pink, red	-do-	Hot
Pentas lanceolata	Pale purple	Cuttings	Hot, rainy
Philadelphus coronarius	White	Cuttings	Spring, Hot
Plumbago auriculata	Pale blue	Cuttings/Offsets	Autumn

Contd.

1	2	3	4
var. *alba*	White	-do-	Autumn
P. indica	Rosy	Cuttings	Winter
Poinciana pulcherrima	Pure yellow	Seeds	Rainy
Porlandia grandiflora	White bracts	Cuttings	Autumn
Punica granatum	Vermillion	Cuttings/Layers	Rainy
Cult. *Florepleno-*	Orange, red	Grafts	Rainy
Nana	White	-do-	-do-
Ravenia spectabilis	Pink	Seeds/Cuttings	Hot
Rondeletia odorata	Orange red with touch of yellow in centre	Layers	Hot, Rainy
Rosa	Various shades	Buds/grafts	Autumn
Roupellia grata	White	Cuttings	Rainy
Russelia equisetiformis	Bright coral red	Cuttings/Div.	Autumn
Spiraea bitulifolia	White	Seeds/Cuttings	Rainy
Stachytarpheta mutabilis	Scarlet	Seeds/Cuttings	Hot
Steptosolen jamesonii	Orange	Cuttings	Winter
Strobilanthes auriculatus	Pale purple	Cuttings	Winter
S. colaratus	Brush purple	Cuttings	Winter
S. dyerianus	Pale blue	Cuttings	Spring
S. scaber	Dark yellow	Grafts	Hot
Syringa juliane	Liliac violet	Grafts	Hot
S. reflexa	Pink	Grafts	Hot
S. villosa	Liliac rose	Grafts	Spring
S. vulgaris	Purple red, dark red, cream yellow, pink, slate blue, liliac pink, white, mauve.	Cuttings	Autumn
Tabernaemontana devaricata	Pure white	Seeds/Cuttings	Hot
Tamarix dioica	Liliac	Seeds/cuttings	Hot
T. juniperina	Pink	-do-	Autumn

1	2	3	4
Tecoma stans	Yellow Golden	Seeds	Autumn
Thunbergia erecta	Deep blue	Cuttings	Hot
var. *alba*	White	Cuttings	Hot
Tibouchina semidecandra	Purple	Cuttings	Flushes
Turnera ulmifolia	Yellow	Seeds/cuttings/ divisions	Autumn
var. *elegans*	Creamy white with dark centre	Seeds/Cuttings	Autumn
Woodfordia fruticosa	Brick red	Cuttings	Spring

Plants for interior decoration

Though plants for interior decorations were used even in Victorian times, conditions were such that only tough plants such as palms, aspidistras and some ferns could survive for any length of time. Today we have choice from hundreds of beautiful plants such as Philodendrons, Hederas, Ficus, Cissus, Bromeleads, Peperomias, Marantas. Flowering pot plants have not been put into this category since these are grown for their flowers and not for their foliage. There are centain plants like Aphelandra that have flowers and also fine leaf markings; these are generally classed as flowering house plants. These though last longer than cut flowers but cannot give lasting attractions of a house plant.

A number of plants, depending upon the skill are used for interior decorations. These range from dried twigs, twisted stems and branches to roots, cut flowers, annuals and foliage plants of various genera and species. Sometimes dried grass panicles form the objects of decoration and art for the drawing rooms. It is not the intention here to discuss the various arrangements of cut flowers which is a specialised subject and discussed in various books on the subject. Similarly Bonsai (dwarf trees) used for interior decorations are not discussed here. Mostly plants like *Pothos aureus*, *Asparagus racemosa*, *Senseviera* and ferns are used for decoration in houses. Various foliage shrubs like *Crotons*, *Acalypha* sp., *Codiaeum* are most commonly employed for decoration in the corridors and verandas. Sometimes, hanging baskets with plants such as ferns, *Asparagus*, *Tradescantia rheodiscolor*, *Portulaca* are used.

Plants for frost proof rooms but unheated

Aichryson domesticum variegatum—A small variegated succulent, a hybrid of garden origin with long oval leaves almost entirely ivory white when young, later turning olive green with an ivory margin.

Aspidistra lurida—Broad dark green leaves having many variegated forms.

Billbergia natans—A terrestrial bromelead with blue bell like flowers.

Chlorophytum comosum—An attractive variegated plant with long narrow leaves.

Cessus antarctica—A climbing plant that will grow anywhere except in very deep shade.

Cordyline inaivisa and *Dracaena parrii*—Palm like plants with many long narrow leaves. In well lit positions.

Cyperus diffusus—Very easy to grow but dull on its own.

Fatshedera lizei—An intergeneric hybrid between Fatsia and Hedera. A tall leggy plant with dark green 5-lobed leaves. Var. *variegata* has leaves with creamy margin.

Fatsia japonica—Variegated form is most attractive.

Hedera helix—Numerous cultivars of the Ivy are available such as Chicago, Pittsburgh, Sagittaefolia, Heisse and Little Eva. species *nepolensis* is in the Himalaya.

Pillosporum engenioides—A shrub with black stems and attracting shaped leaves.

Rhoicissus rhomboidea—Vine like plant with three leaflets.

Saxifraga stolonifera—Leaves marbled.

Sedum-sieboldii c. v. variegatum—Leave blue green round with yellow centre.

Stenocarpus sinuatus—Attractive shrub with Oak like leaves, reddish when first appear.

Tradescantia fluviatilis and *Zebrina pendula*

Plants for rooms with an averge winter temperature of 15°F (10°C).

Begonia rex—Very susceptible to gas fumes. Soil should not be over-watered.

Brassia actinophylla—Vigorous shrub with glossy leaves divided into five leaflets.

Cissus sicyoides—Vine with palmate leaves on crimson leafstalk.

Citrus mitis—Small orange with fragrant white flower.

Ficus benjamina—Attractive small tree with slightly pendulous habit.

Ficus elastica—There are many forms. Best unvariegated form is *decora* variegated forms (*doescheri*, *schryvereana*, *tricolor*) need more light.

Monstrea pertusa—Large leaves perforated with circular holes. Needs good light, if shaded leaves do not develop characteristic attractive perforations.

Pepromia magnoliaefolia, *P. oblusifolia* and *P. glabella*—Small root system, grow in shady situations.

Philodendron bipinnatifidum—Plant with very large much divided leaves.

Philodendron scandens, *P. erubescens*, *P. elegans*—Climbing plants having aerial roots arising from stem at the base of each leaf stalk. They grow best if given cylinders of moss on which they can climb.

Platycerium bifurcatum—This does well fastened to a block of cork wood. The plant must be immersed in a bucket of water from time to time as ordinary watering is ineffective.

Sansevieria trifasciata-laurentii—Tall mottled leaves with cream margins. Should be kept dry during winters and watered moderately only at other times.

Scindapsus aurens—Resemble a climbing Philodendron but has golden variegated leaves. Needs ample light.

Plants for room with winter temperature 55-60°F (13-16°C)

Anthurium scherzerianum—Bright scarlet waxy flowers. Need be grown in mixture with moss and leaf mould, aerated by broken rocks.

Aphelandra squarrosa—Handsome plant with lance-shaped dark green leaves, with prominent ivory veins and pyramids of yellow flowers. Best cultivars are Silver Beauty, Brockfeld.

Codiacum variegatum—Crotons with coloured leaves and different shapes but do not tolerate drought also need a well lit position.

Cordyline terminalis—Broad-leaved 'dracaenas' with crimson young leaves.

Dieffenbachia amoena—Plant with large oblong oval leaves, marbel with cream or yellow. These are poisnous and not recommended where there are children.

Dizygotheca elegantissima—Plant with palmate spidery leaves, striped with shades of silver, cream and yellow.

Ficus lyrata and *F. nekbudu*—Handsome, large-leaved Ficus. Former shaped like violen, white, later has large, oblong-oval leaves with prominent cream veins.

Maranta and *Calathea*-have attractive leaves but must be shielded from direct sunlight.

Pepromia argyria, *P. caperata*, *P. hederaefolia*—have single leaves arising from a common rootstock. There need be kept fairly dry but given a moist atmosphere.

Spathpyllum wallisii—White arm like attractive flowers appear in autumn and spring.

Plantations for Soil Conservation

1. *Stony hills and rocky outcrops*—These are the barren rocks available for plantation in arid and semi-arid areas comprising of sand stone, rhyolite and granites of Aravelli and Vindhyan formation. In peninsular India, these consist of granite formation, Dharwar schist and Dolerite characterised by small and big boulders (Gupta 1971). A few occasional trees of *Acacia senegal*, *Anogeissus pendula*, *Grewia tenax*, *Commiphora mukul*, *Capparis* bushes, *Maytenus emarginata* and *Zizyphus nummularia* are seen. The vegetation of these rocky outcrops in S. India has been described as discontinuous spiny formations or scattered shrubs under the series *Albizzia amara-Acacia latronum*, *Acacia arabica* and *Anogeissus-Chloroxylon-Albizzia amara* (Gaussen *et al.*, 1961, 1963, 1964 a, b, 1966, 1972). These hills are generally bare except the interspaces of the boulders where some soil has accumulated. Granite hills support a community of *Euphorbia antiquorum* and *Cassia auriculata*. However, scattered plants of *Ailanthes excelsa*, *Acacia leucophloea*, *Pongamia glabra*, *Zizyphus xylopyrus*, *Eriodendron anfractuosum* and shrubs of *Cassia fistula*, *Carissa spinarum*, *Dodonaea viscosa* and *Opuntia dilleni* are not uncommon. The vegetative cover of these areas need be improved under this programme where such areas may be managed as mini-wood lots for fuel and fodder species. There is practically no soil cover except in depressions where microclimate and soil conditions are somewhat favourable. On such situations, 30-40 cm soil depth might be sufficient for plantations. Presprouted stumps of *Prosopis juliflora* in 60 cm^3 half-filled pits, exhibited increased mean height increment in arid Rajasthan. Though *Acacia senegal* show good survival, mean growth rate is slow (20 cm/annum).

The foot-hills comprising of semi-rocky or gravelly areas are formed by the deposition of colluvial silt, rock fragments and grit. The natural vegetation on such areas consist of *Acacia* *senegal*, *Prosopis cineraria*, *Zizyphus nummularia*, etc., alongwith many grasses. Ridge cum trench type of soil working is most suitable for sowing such areas. *Acacia senegal* and *Cassia auriculata* survived and put on high growth. Among the various species tried (*Albizzia amara*, *Azadirachta indica*, *Feronia elephantina*, *Holoptelea integrifolia*, *Kigelia pinnata*, *Prosopis cineraria*, *P. juliflora*, *Parkinsonia aculeata*, *Tamarix indica* and *Tecomella undulata*), as transplants in 60 cm^3 pits at 5 m × 5 m distance, only *Albizzia amara*, *Azadirachta indica* and *Prosopis juliflora* were successful both as percentage survival and mean annual height increment.

Some of species recommended on the hill slopes on different soil-climatic regions are :

Hills of Bihar and Orissa : *Acacia auriculaeformis*, *Anacardium occidentale*, *Pinus khasia*, *Grevillea robusta and Eucalyptus hybrid.*

Hills of South India : *Eucalyptus globulus*, *Acacia mearnsii* (Nilgiris) *Tectona grandis.*

Hills of Himalaya : *Acacia catechu* (Siwaliks), *Buxus sempervirens*, (*on limestone*) *Dalbergia sissoo* (*on low hills*), *Alnus nepalensis*, *Bombax ceiba*, *Alstonia scholaris*, *Grewia oppositifolia*, *Morus indica*, *Pinus roxburghii*, *Robinia pseudacacia*, *Ulmus wallichiana* *Ficus* sp. *and Quercus incana.*

Hill regions of arid zone : *Commiphora wightii*, *Anogeissus pendula.*

2. *Unstabilised and shifting sand dunes*—The unstabilised dunes are of the shifting type and are generally devoid of any vegetation. Nevertheless when stable, the natural flora consist of *Calligonum polygonoides* (Phog), *Crotalaria burhia* (Sannia), *Leptadenia pyrotechnica* (Kinmp), *Citrullus colocynthis* (Tumba) with some grasses like *Cenchrus biflorus*, *Aristida* sp. and *Cyperus arenaria.* The interdunal areas are characterised by the presence of few species like *Capparis decidua* (Karil), *Zizypus nummularia* (Bordi), *Haloxylon salicornicum* and a few trees of *Prosopis cineraria.* Shifting sand dunes have a better moisture regime

as compared to the stabilised dunes and from afforestation view point are considered to be a better habitat than stabilised dunes. Care has to be taken that all the operations of afforestation are done at the same time since even casualty replacement becomes difficult at later stages due to reasons of moisture limitations. The interdunal areas naturally have better soil moisture status than dune slopes and are naturally easier to plant than dune slopes.

Techniques for plantation and stabilisation of sand dunes essentially consist of the following steps :

1. Closing the area against grazing and browsing by cattle and construction of a peripheral bund along the south and south-west closure effected through barbed wire fencing.

2. Mulching with brush wood has been advocated at the Central Arid Zone Resarch Institute, Jodhpur. Brush wood, locally available, consist of *Crotalaria burhia*, *Calligonum polygonoides*, *Leptadenia pyrotechnica*, *Zizyphus nummularia* and grasses like *Panicum antidotale*, *Lasiurus sindicus*, etc.

3. In arid regions of Haryana and Shekhawati zone of Rajasthan, tussocks of *Erianthus munja* (Kana) consisting of a rootstock and 12-20 cm shoot are planted 25×25 cm apart during rain by digging sand 15 cm deep on dune crest. Entire root portion and a part of shoot (about 3 cm) is burried in sand. Tufts start sprouting within 7-10 days of planting. During the first year, shoots attain average height of 72 cm and on an average about 10 per cent tufts fail to sprout which are replaced next year.

4. Simultaneously with Kana planting, species like *Citrullus colocynthis*, *Calotropis procera*, *Calligonum polygonoides*, *Tephrosia purpurra*, *Leptadenia pyrotechnica* etc. are introduced. Natural recruitment of grasses and sedges like *Cenchrus biflorus*, *Cyperus arenaria*, *C. iria*, *Aristida* sp. alongwith other plants like *Gisekia pharnacoides*, *Mollugo cerviana*, *Tephrosia purpurea* and *Crotalaria burhia* is noticed in the first year. Thus a black crust is formed on the surface of the sand dune.

5. Trees and shrubs such as *Acacia senegal*, *Prosopis cineraria*, *P. juliflora*, *Zizyphus mauritiana*, *Balanites aegyptica*, *Parkin-*

sonia aculeata, *Salvadora oleoides*, *Acacia nilotica* ssp. *indica*, *A. modesta*, *Azadirachta indica*, *Ricinus communis*, *Dalbergia sissoo*, *Albizzia lebbek*, *Tecomella undulata* are introduced either by sowing or planting in 50 cm^3 pits dug in sand.

Areas in Jhunjhunu district were fenced with angle iron posts and barbed wire, whereas the thorns of *Zizyphus nummularia* were used for the purpose in Bikaner. After fencing, these areas were mulched in their respective years of formation by erecting mechanical barriers at 2-3 m apart across the prevailing winds. Following this 9-12 months old transplants of tree species viz. *Prosopis cineraria*, *P. juliflora*, *Acacia tortilis* and *Calligonum polygonoides* raised in planting bricks and containers were planted at spacing of 5 m^2. Just before the onset of monsoon, seeds of same tree species and grass species viz. *Cenchrus ciliaris*, *C. setigerus*, *Lasiurus sindicus*, *Panicum turgidum* and *Rhynchosia minima* were sown in lines 2-5 m apart. In Jhunjhunu borders of each compartment were planted with the rootslips of *Saccharum bengalensis*.

Studies have shown (Bhimaya *et al*., 1964) that 1 year old transplants raised in planting bricks on the leeward side of the mulch barrier or microwind breaks prepared by locally available dry shrub material are successful in extreme dry regions of Rajasthan. Choice of species again will depend upon the rainfall. Between 200-300 mm rainfall, *Balanites aegyptiaca*, *Cordia rothii*, *Prosopis juliflora*, *Acacia tortilis*, (between 200-400 mm) *Ailanthes excelsa*, *Albizzia lebbek*, *Prosopis cineraria* and *Zizyphus mauritiana* are successful and show better survival and growth. Branch cuttings and seedlings of *Calligonum polygonoides* are extremely successful, the roots of which provide 80 percent of the fuel requirements of Bikaner district. *Prosopis juliflora* coppices provide fuel in the relatively humid tracts of Rajasthan desert (districts like Jodhpur, Pali, Jalore, etc.) since it is sensitive to frost and do not show any growth on sand dunes. *Acacia tortilis* has shown relatively a better performance (Gupta and Balara, (1972) and is now used extensively in the sand dune afforestation programme in Haryana and adjoining areas. However, use of *Zizyphus mauritiana* is on a limited scale though it is promising for relatively better soil climatic conditions.

Some of the species like *Acacia tortilis*, *A. senegal*, and *Prosopis cineraria* are raised by seed sowing in bricks of 30 cm high, 10×15 cm base and 10×10 cm top in nursery and in polythene bags of size 30×20 cm (150 gauge). Earthen bricks with plants ranging from 30-40 cm height in case of *A. tortilis* are carried to site and planted in pits of 60×45×45 cm size which are refilled with dug out earth to a depth of 35 cm at planting time. Similarly, plants raised in polythene bags are carried and planted after opening the bottom of the bags. Spacing adopted is 4 m×4 m. If possible, 2-3 spot irrigations are provided @ 15 lit. of water per plant. Two weedings and hoeings are carried out during the first year around plants to a distance of about 0.5 m and the area around plants is mulched to conserve moisture. Damage to frost is avoided by covering the plants. CAN (Calcium Amonium Nitrate) @ 10 kg per 100 pits, if applied during rains, boosts the growth considerably. The cost of such plantations is recorded at Rs. 550/- per hectare.

In the Haryana state, sand dune stabilisation works have been undertaken in Mohindargarh, Bhiwani, Rohtak (Jhajjar and Nahar Tehsils) and parts of Hissar and Sirsa districts. These activities have provided adequate employment to rural population. Besides the social benefits the activities have provided protection against air-pollution, supply of increase timber, firewood, grass and lopping.

The expenditure is approximately Rs. 1,200/- per ha till establishment (3-5 years) period. Similarly, grassland development in the plain area costs Rs. 1,200/- for first and second year and cultural operations like weeding and use of fertilizers may range upto Rs. 100/- annually from third year onward. Revenue is expected as per details given below : (Anonymous 1977).

	ann./ha
Sale of Kana (Saccharum) from 3rd year to 7/8th year.	40
Sale of castor 1st to 4th year.	40
Firewood from sand dune fixation works ($3\ m^3/h/year$).	200

Ber fruit from 7/8th year (75 @ Rs. 20/- per tree).	1500
Sale of grass from 2nd year (20 q. @Rs. 5/- per quintal).	100
Total :	Rs. 1880

Coastal Sand Dunes

Two distinct forms of migratory sands are perceptible in peninsular India; a) Sand dunes formed as a result of aeolian depositions consisting of extensive deposition of loose shifting red sands. During the months of May-September which is accompanied by South-west monsoon dry surface of the broad belt of red loam is swept clean by these winds. The vast clouds of red dust are carried eastwards to the coast and they meet the sea breeze which on precipitation gives rise to the red sand hills or "Teris". These are characteristics of Tirunnelveli district (Kudiraimozhi Teri), Madurai (Bodi Thevaram areas) and Ramanathapuram districts in Tamil Nadu state. b) Sand dune formation of Rameshwaram island where high velocity winds (45 km/hour) blow during May-August. The wind first picks the soil particles, disengages it from other mass of sand, rolls them on the ground and finally carries them with the wind (surface creep). The size of the soil particles carried depends on the velocity of the winds. The direction of this movement is dependent on wind direction. During north-east monsoon season, the whole process is again set in motion in the reverse direction. Wind erosion during this season, is considerably reduced since the island gets annual rainfall during these months. The sand dunes are linear with coarse sandy soils devoid of organic material, infertile with colloidal property thus exposing the sands to ranges of high velocity winds. The sand is *generally* with white efflorescence. Increased activities by human beings for fuel and his agents like cattle, goat and sheep for grazing have resulted in strong ecological imbalances in the region, thus, aggrevating the process of erosion in this ecosystem.

Afforestation programme : Since 1848, attempts were made to stabilise these sand dunes. Among the various efforts attempts to encourage ryots to take up blocks of land on Cowle tenure and to plant the area gradually with tree growth are noteworthy. Palmyra (*Borassus flabellifer*) trees in conjuction with field crops were possible to take up. Besides palmyra, seeds of *Acacia planifrons, Datbergia multiflora* and *Dodonaea viscosa* were sown, with ragi (*Eleusine coracana*) and other cereals. The private enterprise failed, presumably due to deeper water table and shifting sands. Later the area was reclaimed only through governmental agency. In 1892, an area of about 13,400 acres was reserved in Kudiraimozhi,—Teri and sizable portions were taken up for planting with Palmyra but on account of slow growing nature of this species in early stages of its growth the plantations were submerged by the moving sand. Presently, Working Plan for the tract suggests species like Cashew (*Anacardium occidentale*) and *Acacia planifrons* at an espacement of 3.5 × 3.5 m besides palmyra. In order to protect young seed-, lings of these species from dessicating winds, palmyra fronds are erected around the plants. To a small extent, species like *Tecoma stans* and *Acacia auriculaeformis* have also been introduced recently. Some of the tracts like Thevaram and Devadaman in Tamil Nadu still pose afforestatton problems because of prevailing fierce winds prevalent during south-west monsoon blowing in through gaps of western ghats.

Afforestation of coastal dunes such as of Rameshwaram island apart from other factors pose problems of "physiological drought" because of saline water and salt spray. On such situations, xerophytic crops of plant like *Casuarina equisetifolia* is planted. Broad-leaved species having no xerophytic adaptation are totally unsuccessful. Smaller dunes can be fixed with plants like *Spinifex littoreus* while the moisture depressions are clothed with *Pandanus tectorius, Calotropis gegantea, Ipomoea biloba* and sedges. Some of the areas have natural growth of *Acacia planifrons* which has been used as windbelt. Though use of bitumen emulsion and other petroleum products for spray have been advocated in order to immobilise shifting sand particles, it is expensive and not practicable because of several reasons. Unrestricted grazing and browsing by large number of bovine populetion is perhaps one of the many reasons. The average cost of *Casuarina* plantations has been rpeorted to Rs. 1,200/- per ha. The rotation is fixed at 8 years and the average price is expected at Rs. 4,000/- to Rs. 5,000/- per ha.

Since 1970, Soil Conservation Organisation of Orissa state had been working at Golabandha for planting species like Cashewnut and *Casuarina* on sterile and inhospitable coast dune sand. Tank silt and red earth were applied to the pits before actual planting. After experiencing the bad effects of cyclones adequate protection to plantations by way to raising screen consisting of 20 rows of *Casuarina* along the coastal line was provided. To ensure optimum vegetative growth, a 3 m high barricade with proper anchorage is provided which is very effective in protecting young *Casuarina* seedlings from the effects of drifting sands and salt laden winds. In the interspaces of *Casuarina* shelterbelt, *Cocos nucifera* is planted. Since the perched sweet water-table is present at 1-1.5 m below the surface, this water provides source for irrigation. 2 pitchers at an interval of 3 days are provided to each plant manually. Survival percentage of Coconut is as high as 80 per cent. The plantation techniques and cultural operations as advised by the Central Plantation Crop Research Institute at Kasargod are followed. The Coconut plants have started bearing. The Cashew plantations are recorded to have given 1889 kg and 7548 kg of kernels during 1976-77 and 1977-78. Initially Cashew plants were provided with *Casuarina* guard plants for protection against sand drifting but these are recorded to have an adverse effect on plant growth.

Since India has a vast coastal belt about 500 km only in Orissa, such plantations all over would not only provide employment to coastal fishermen folk but also add to the production from these lands which otherwise are subjected to erosion and loss of soil fertility.

Ravine afforestation

Techniques used for afforestation of ravines consist of sowing seeds in trenches of 3m × 60 cm × 45 cm (10′ × 2′ × 1½′) placed at 3m apart. The plants are spaced at 5m distance. Soil working is completed by the end of March. Dug-up earth is filled ½ in trenches and half at the ridge. Refilling is done by end of May. Sowing is completed before 15th of June. One line of sowing is done at the ridge top (border of dug-up portion) and the other line of sowing in trench. The species selected are *Azadirachta indica*, *Prosopis juliflora*, *Dalbergia sissoo*, *Albizia procera* and *Pongamia glabra*. *Eucalyptus* is not successful. Three weedings are done. The plants are thinned at 4th year as cleaning. Total cost of planting is reported at Rs. 500/- per heetare. At certain locations *Tectona grandis* has been found successful. Ravine beds can be planted with *Dendrocalamus strictus*, *Zizyphus* etc. The slops are more often grazed by animals.

These plantations are managed at 15 years rotation by clearfelling. Grass is exploited every year. Grazing is not allowed for initial 5 years, after which grazing is allowed and a fee @ Rs. 1.50 P. per cattle and Rs. 3.00 per buffaloe is charged. The return from the area is variable, the average being Rs. 700/- per ha with M.F.P. of Rs. 125-250/- per hectare of the value.

It is estimated that about 3.67 million ha of land in the country is effected by severe gully erosion (1.12% of total area). These gullied lands often called as the ravines are commonly associated with some rivers and their tributaries and are a menace to the adjoining table lands. The table lands suffer from sheet and rill erosion which ultimately goes un-noticed, forming gullies. This not only results in a bad land topography, but the land is lost with considerable sediments contributing to the river system. These areas get denuded thus loosing their fertility and productive capability and are very often used as hiding places and a refuge by the dacoits in some parts of Rajasthan, Madhya Pradesh and Uttar Pradesh.

Table : 8 Following table records the extent of gullied lands in the country.*

	Rivers and their tributaries	Approximate area in million ha
U.P	Yamuna, Chambal, Gomti, Betwa and Kholas of river Ganga	1.230

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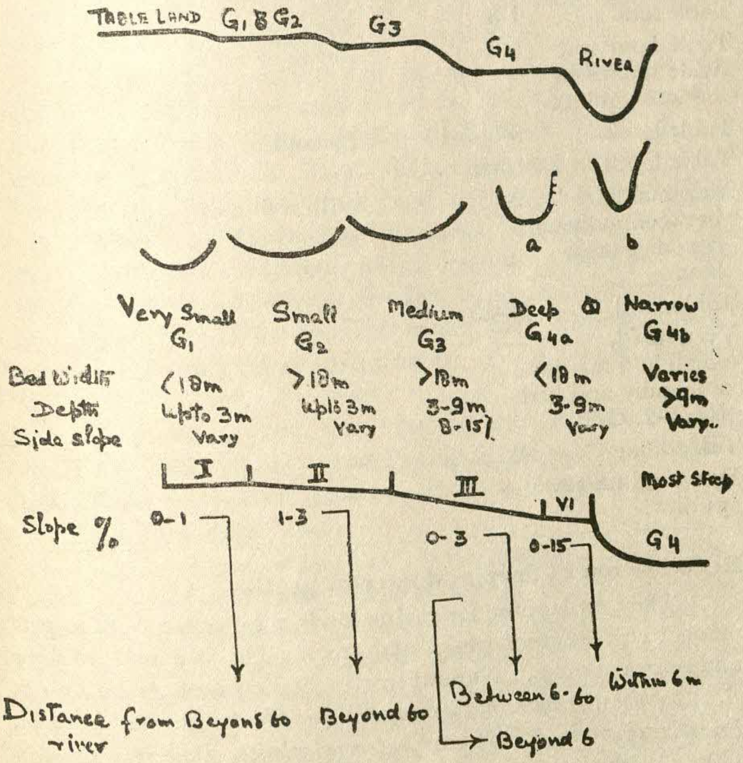
*1965 Study on Survey and reclamation of ravines in India. Committee on Natural Resources. Planning Commission New Delhi pp

Contd.

M.P.	Chambal, Assan, Kali Sind	0.683
Rajasthan	Chambal, Parwati, Kali Sind, Mej Mangli, Banas, Parwan, Alnia, Talira, Ghora-Pachar, Morel,	0.452
Gujarat	Ban-Ganga and Sabi (Bhulyan 1967)	0.400
Maharashtra		0.020
Punjab	Ghagar, Sutlej, Beas	0.120
W. Bengal	Kangasbat	0.104
Bihar		0.600
Tamil Nadu		0.060
	Total :	3.669

Gently stoping nature of the land, loamy sand, sandy loam and silty loam texture of the soil, intense rains in monsoon, improper landuse by way of over-grazing, biotic interference with natural vegetation and faulty agriculture practices are the chief causes of gully erosion. Even on table lands sheet erosion is going on a very large-scale un-noticed. Each gully during the course of its development, is recorded to pass through a cycle of three stages (Tejwani *et al.*, 1960). If the soils are alluvial in nature and of very great depth this cycle keeps repeating and with passing of each cycle the gully goes on extending in length, breadth and depth.

The gullied system has been classified (Bennet 1939, Ayres 1939, Ireland *et al.*, 1939, Tejwani & Dhruvnarayan 1961). Any system of gullies has an independent catchment having a regular stream which is termed as 'drainage system'. In each drainage system, gullied with defined side slope, bed width and depth occur in certain order, viz. in upper reaches gullies are wide and shallow with varying side slopes, in middle it is relatively deeper, wider and has uniform side slopes upto 15% while in lower portion near the river, it is very deep, has steep side slopes and associated with branch gullies. Figure represent this system schematically.



Land capability and classificatcoin of Ravine lands (After Tejwani 1970)

Table 9. This system for reclamation has been divided into the following land capability classes :

Landform	Slope (%)	Distance from gully river (m)	Land capability class
Table land	0-1	Beyond 60	I
Table land	1-3	-do-	II
Table land and wide humps in between gullies	0.3	Between 6-60	III
Table lands	3-5, 5-10	Beyond 6	III
Table lands	10-15	-do-	IV
Marginal land between gully ring and table land	0-15	Within 6 m of gully ring	VI
Table land	15-25	—	VI
Very small, small and medium side gully and beds (G, F-2, G-3)	—	—	VI
Table land	25	—	VII
Deep and narrow gullies	--	—	VIII

Reclamation of deep and narrow gullies

The best landuse for ravine lands is to retire them to permanent vegetation of grass and trees. This is a must of deep and narrow gullies. Natural tree vegetation is of *Acacia senegal, A. leucophloea, Azadirachta indica, Albizia lebbek, Feronia elephanta, Prosopis cineraria* in Gujarat, *Acacia nilotica, Dalbergia sissoo* in U.P. With closure to grazing these species regenerate. *Prosopis juliflora* is very agressive and dominates in some places. *Tectona grandis* has suceessfully been tried in Gujarat while on gully beds *Dendrocalamus strictus* has been found very successful. For Agra region, *Pongamia pinnata, Holoptelea integrifolia, Acacia nilotica* ssp. *indica* and *Albizia lebbek* have been found suitable. *Acacia catechu*, a shrub type has been widely used in Yamuna ravines. In Kota region, *Salix tetrasperma* in gully bed and *Acacia nilotia* on top and marginal lands have been found to be most suitable. The area need to be closed from grazing and other biotic interferences. The annuals with closure (*Aristida funiculata, Themeda triandra*) are replaced by perennials (*Eremopogon foveolatus, Heteropogon contortus, Dichanthium annulatum* on medium heavy soils and *Cenchrus ciliaris* on light soils). The loss of soil progressively decreases. Closure to grazing is recorded to reduce soil loss from 3.3 tonnes/ha under over-grazed condition to only 0.6 t/ha (Mirchandani *et al.*, 1958).

The growth of gullies can be checked through contour and peripheral bunding which could be of different specifications for semi-arid areas of Gujarat. Buds of 0.9 to 1.2 sq m cross-section spaced at 90 to 120 cm vertical interval are recommended. However, these need be stabilised by sodding with grasses like *Dichanthium annulatum, Cenchrus ciliaris* and *Panicum antidotale.* In Chambal ravines, where soils are relatively fine and rainfall is more, graded bunds in association with grassed-waterway and drop structure for safe disposal of water are recorded much better than contour bunds (Rajbans Dayal 1967).

Gully plugs protect deepening of gully beds by reducing speed of runoff water, redistributing it, increasing its infiltration, encouraging silting and improving soil moisture regime for establishing plant cover.

Various material such as brush wood, live-hedges, earth sand, brick masonary and boulders are in use for gully plugs. The types of gully plugs depend on the width, length and bed slope of the gully and anticipated runoff. Very deep and vertical gully heads in association with the phenomenon of undercutting or caving need urgent attention. Generally in order to heal these vertical and active gully heads by providing natural angle of repose, valuable table land has to be encroached to a great extent. The most economical operation adopted to stop progress of gully head is to fill in the caved face of the gully head upto 2/3rd length of the vertical face. The newly formed slope is stabilished by sodding or sowing with a suitable grass (e.g. *Dichanthium annulatum* or *Cenchrus ciliaris*) and constructing a series of small brush wattles across the slope. This type of treatment is financially justified when these active, vertical and caved gully heads are threatening to undermine bridge abutments, rail and road embankments and buildings.

4. **Torrents beds**—This situation is characterised by coarse sediments, low nutrient status, loose and unstable planting sites, low moisture availability, flashy flows and abrassive action of moving debris. Planting material on such situations, therefore, should be easy to propagate, quick growing and strong with deep and spreading root system. For training of torrents, both vegetative and mechanical measures are needed in the form of spurs to divert the flow of water in the stream. Among the plant material used for spurs are *Arundo donax*, *Vitex negundo*, *Ipomoea carnea*, etc. which have been found useful.

The torrent beds could be successfully planted with species like *Dalbergia sissoo* and *Acacia catechu*. The experiments carried out at the Central Soil & Water Conservation Research and Training Institute, Dehra Dun, have shown that *Dalbergia sissoo* at 9.15 m × 9.15 m spacing has put in best height, diameter and crown spread. Under a wider spacing of 18.30 × 18.30 m the interspace could be utilised for a forage species such as *Chrysopogon fulvus* (av. yield being 15,000 kg/ha). Under closer spacing, the grass yields are reduced (Anonymous, 1974*a*).

5. **Saline-alkali Soils of depressional areas**—There are primarily two methods of afforesting such areas which are formed either by impeded drainage and water-logging or application of salt water continuously over a period of time. Considerable areas of such wastelands are found in plains of Punjab, Haryana and Uttar Pardesh having such Usar lands. Priority for reclaiming such areas for crops and the method of reclaiming has been demonstrated by the Central Soil Salinity Research Institute (Anonymous 1974*b*). However, the intention here is to give utilisation of such areas for fuel and fodder. There are two methods for planting such areas, viz. (i) by growing saline-alkaline tolerant species without any reclamation and ii) by first improving soil conditions. It has been observed that on such soils, plant species having inherent capacity of producing a prolific root system are able to survive and resist salt concentrations and low moisture supply. Among the various species, *Acacia nilotica* ssp. *indica*, *Azadirachta indica*, *Albizia*

lebbek, *Butea monosperma*, *Madhuca indica*, *Prosopis juliflora*, *P. cineraria*, *Tamarindus indica*, *Salvadora persica*, *Tamarix dioica* are promising alongwith some shrubs like *Vitex negundo*, *Ipomoea carnea*, *Alhagi pseualhagi*, *Indigofera paucifolia*, etc.

Soil working on such sites should aim at producing a suitable mass of loose soil amenable to rapid proliferation of root system and maintaining salt free condition of soil mass thraugh leaching. To achieve this ridge method of soil working is suitable. Studies carried out at the Central Soil Salinity Research Institute (1974) on five species, viz. *Albizia lebbek*, *Eucalyptus hybrid*, *Prosopis juliflora* and *Terminalia arjuna* on saline-sodic soil under different soil working techniques showed interesting results. Overall position of different soil treatments with regard to plant survival and growth was in the order of normal soil/gypsum + FYM/Gypsum/FYM/original soil. Fertilizer application increased height growth only in treated soils. However, in general, *Eucalyptus hybrid* and *Prosopis juliflora* showed the best performance while *T. arjuna* was inferior in suchsoils.

Singh (1970) described utilisation of saline-alkali soils for agro-industries without prior reclamation by planting the follwing plants :

Essential oil bearing —*Anethium*, *Apium*, *Ocimum*.
Edible oil —*Carthamus*, *Helianthus*, *Guitzotia*.
Non-edible oils —*Alangium*, *Azadirachta*, *Pongamia*, *Salvadora*.
Perfumes —*Rosa*, *Polyanthes tuberosa* and *Jasminum*.
Gum —*Sesbania*, *Cyamopsis*.
Fibre —*Gossypium*, *Agave*, *Hibiscus*.
Tannin —*Woodfordia*, *Anogeissus latifolia*, *Lawsonia inermis*, *Cassia auriculata* and *Punica granatum*.
Starch bearing —*Canna edulis*, *Maranta arundinacea*, *Curcuma zeodaria*.
Sugar —*Beta vulgaris*
Forage and Halophytes —*Brachiaria mutica*, *Cynodon dactylon*, *Pennisetum purpureum*, *Suaeda fruticosa*, *Salsola* species, *Cressa cretica*, *Trianthema* sp., *Sensuvium portulacastrum*.

Flora of a typical salt basin at Pachbhadra has been studied (Saxena and Gupta, 1972), showing typical plants of this habitat. Salt tolerance of various desert grasses has been studied (Gupta and Sharma, 1970) and according to salt tolerance, the grasses may be classified as below :

Highly salt tolerant —*Sporobolus pallidus*, *S. helvolus*, *Chloris gyana*, *Cynodon dactylon* and *Paspalum notatum*.

Medium —*Brachiaria mutica*, *Cynodon plectostachyum*, *Lasiurus sindicus*, *Aristida hystris* and *Echinochloa colonum*.

Low —*Panicum antidotale*, *Cenchrus ciliaris*, *C. setigerus*, *Dichanthium annulatum*, *Eragrostis tremula* *Cymbopogon martinii*, *Dactyloctenum sindicum* and *Eleusine compressa*.

Such areas could profitably be used as sanctuary for herbivores like Black buck and Gazelle and as grazing ground for the livestock. The soil conditions show improvement in due course of time because of leaf litter, decay of root matter and addition of organic matter from animal droppings. However, their utilisation on carrying capacity need be managed on scientific lines to avoid over-utilisation.

Littoral regions in the estuaries of rivers, creeks and lagoons, low tide and flats of sea coast are the places experiencing conditions of water-logging with saline water. The soil is silty loam or stiff clay. Aeration is defective and the sites are physiologically dry. Xerophytic foliage under such conditions is helpful to tide-over the ecological conditions. Various devices such as stilt roots, knee roots, pneumatophores, lenticels on roots develop. Species like *Salvadora oleoides*, *Pongamia glabra*, *Acacia nilotica* ssp. *indica*, *Azadirachta indica*, *A. leucophloea*, *Tamarix gallica* and *Butea monosperma* can be raised on such soils depending upon the proportion of fine clay, salinity status and level of humus. *Lannea grandis* is successful on raised mounds after washing out salts in 2 rainy seasons. Similarly, *Casuarina* *equisetifolia* may be planted on artificially raised mounds. Some of the grasses that would stand water-logging conditions are *Arundo donax*, *Desmostachya bipinnata*, *Brachiaria mutica*, *Paspalum dilatatum*, *Cyperus corymbosus*, *Dactyloctenium aegyptium*, *Clinogyne dichotoma*, *Saccharum munja*, *Sporobolus* sp., *Cynodon dactylon*, *Pennisetum purpureum*. There are certain shrubs and undershrubs which can tolerate saline conditions and are valuable as forage such as *Salsola sp.*, *Haloxylon salicornicum*, *Suaeda fruticosa*, *Atriplex*, *Trianthema*, etc. Some of the salt loving plants such as *Cressa cretica* are some times used as forage in some parts.

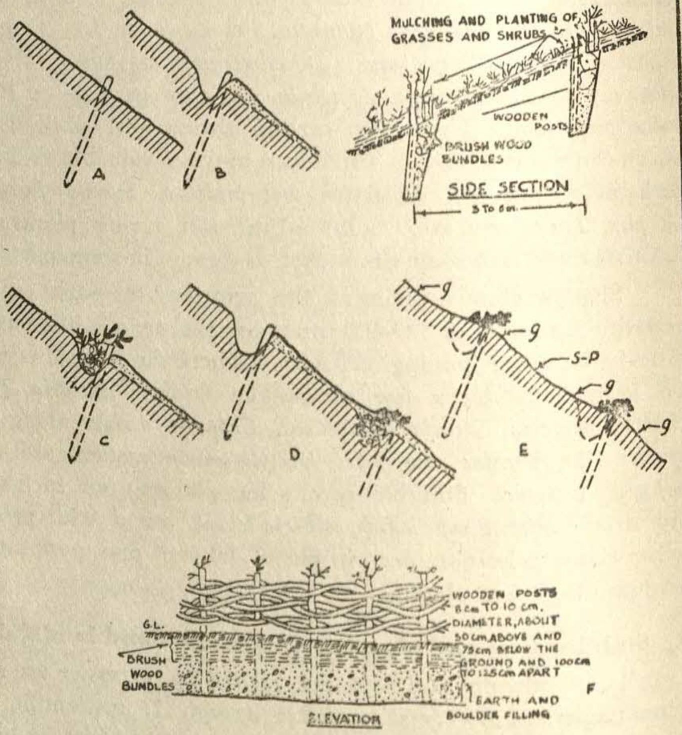
Shallow alluvial plains in the arid and semi-arid regions receiving a rainfall of 300-400 mm are slightly alkaline having a moderate water-holding capacity. There the natural vegetation is sparse having a few species like *Prosopis cineraria*, *Zizyphus nummularia*, *Acacia leucophloea*, *Capparis decidua* alongwith grasses like *Eleusine compressa*, *Dactyloctenium sindicum* and *Eremopogon foveolatus*. Suitable species for planting on such sites are *Acacia nilotica* ssp. *indica*, *Albizia lebbek* raised with proper soil working technique, deep in pits of 60 cm^3 and perforating hard pan to 90 cm depth.

6. Stabilisation and planting of landslips and landslides

The landslides and slips are caused by excessive use and mismanagement of vegetative covers through 1. unscientific removal, overgrazing and fire, 2. cutting of roadsides in hills, 3. poor maintenance of terrace risers in the hills, 4. unstable and week geology, 5. seismeic disturbances or blasting, 6. unscientific mining and stone quarrying associated with improper road alignments, 7. toe cutting by hill torrents and 8. excess water discharge from the upper catchments. The control and stabilisation of these landslips involve both engineering and vegetative measures. Once these are stabilised, they can be put to more productive use through plantation of economic species. The control measures generally involve the following steps—

(i) Enclosure of the area in order to control excessive grazing and exploitation of trees and shrubs.

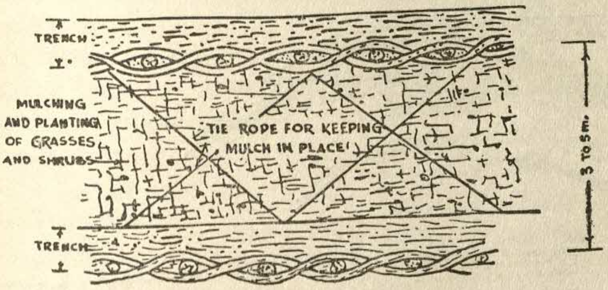
ii) Construction of a retaining wall which could be of gabion structures or of stone masonary. Care has to be taken


A
B
MULCHING AND PLANTING OF GRASSES AND SHRUBS
WOODEN POSTS
BRUSH WOOD BUNDLES
SIDE SECTION
3 To 5 m.
C
D
E
g
g
S-P
g
g
G.L.
BRUSH WOOD BUNDLES
WOODEN POSTS 8 cm TO 10 cm. DIAMETER, ABOUT 50 cm ABOVE AND 75 cm BELOW THE GROUND AND 100 cm TO 125 cm APART
EARTH AND BOULDER FILLING
ELEVATION
F

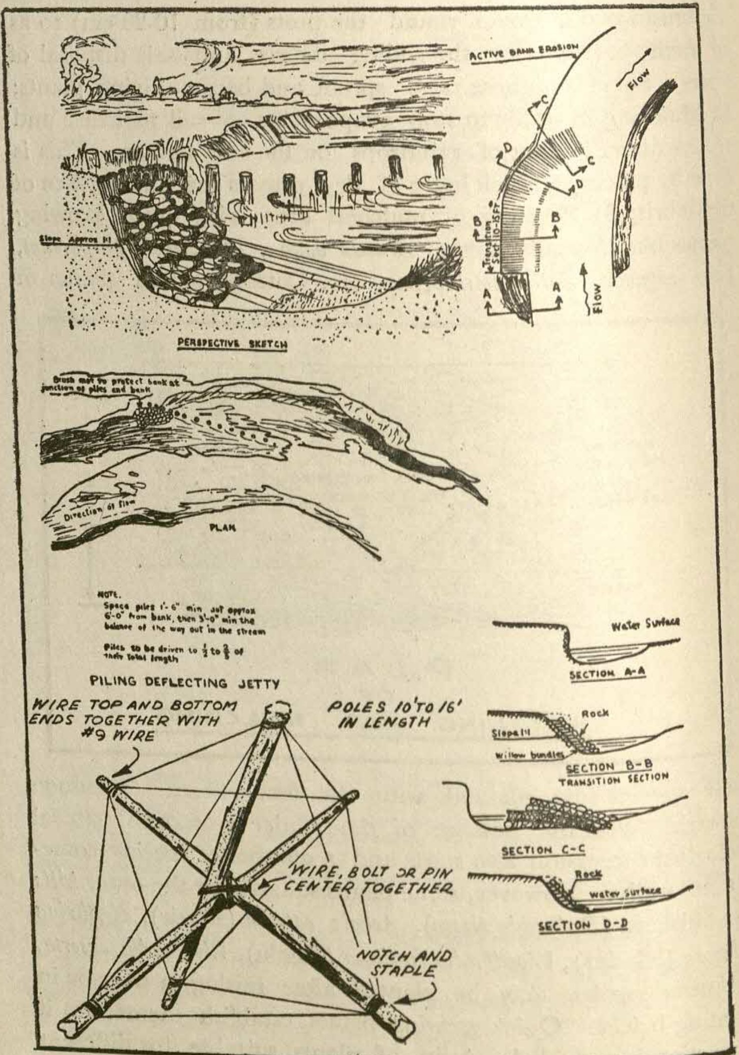
Steps in contour wattling and planting: A, Skakes set in contour rows. B. Trench cut just above the stakes. C. Brush watties packed into trench resting against stakes. D. Lower contour completed, with brush wattling party burried by soil from next trench above E. Sowing and planting. (g. Planting of grass and low shrubs S.P. Planting of shrubs and trees).

that there is proper provision for disposal of rainwater if it is on the roadside. If the toe wall/retaining wall is near the hill torrent, this has to be protected by constructing suitable spurs either vegetative or gabion construction.

(iii Protection of bare slopes through 1) breaking the slope by providing contour wattlings to suitable (5-7 m) intervals. 1 m trench is dug up and filled with brush wood bundles (5-6 cm diameter). Posts of plants like *Lannea grandis*, *Vitex negundo*, *Salix tetrasperma*, *Spermadictyon suaveolens* and *Erythrina suberosa* available locally, are planted in trenches at 1 m interval and the brushwood is woven round the posts (from 10-20 cm) so as to form barriers for the sliding debris and safe disposal of water. Some of these also sprout and become living plants; 2) Mulching in order to stop evaporation of soil moisture and reduce direct impact of raindrops on the soil surface. This is done by placing a thick layer of dry grasses on the surface of the debris; 3) Planting of mulched area with quick growing species like *Ipomoea carnea*, *Arundo donax*, *Pennisetum purpureum*, *Vitex negundo*, *Salix tetrasperma*, etc. Cuttings/rooted plants of these species are planted with the first effective monsoon showers. With the passage of time under protection, natural ecological succession also starts and a number of species come-up naturally. However, some plants suitable for the outer *hills* like Shisham (*Dalbergia sissoo*), *Acacia catechu* (Khair), *Erythrina suberosa* (Madar), *Woodfordia fruticosa* (Dholu), *Wenlandia exserta*, *Boehmeria rugulosa* may be planted after raising in bags or in planting bricks. Quick growing plants establish themselves if protection is provided. A list of plants suitable for different elevations is given in Table 8. Plants with deep root system and a good crown cover are preferred (Meghan, 1977) over shallow rooted plants; 4) Selection of plants for mine-spoiled areas will depend on their specific soil requirements such as *Bauhinia retusa* for limestone quarries, *Moringa pterygosperma* for


TRENCH
MULCHING AND PLANTING OF GRASSES AND SHRUBS
TIE ROPE FOR KEEPING MULCH IN PLACE
TRENCH
3 TO 5m.

PLAN OF WATTLING AND MULCHING



NOTE.
Space piles 1'-6" min out approx 6'-0" from bank, then 3'-0" min the balance of the way out in the stream

Piles to be driven to $\frac{1}{2}$ to $\frac{2}{3}$ of their total length

PILING DEFLECTING JETTY

areas with rock phophate mining. However, this aspect needs further research on introduction and screening of suitable plant species for specific site conditions such as iron, mica, limestone, Aluminium, Tungsten, Gypsum, etc.

Table 9. Plants for slope stabilisation.

1000-4000 ft (305-1219 m)

Grasses

Cynodon dectylon (Stoton)
Eulaliopsis binata (tussock)
Chrysopogon fulvus (-do -)
Saccharum munja (- do -)
Dendrocalamus strictus (Rhizome)

Arundo donax (Cuttings)
Pennisetum purpureum (Cuttings)

Shrubs

Vitex negundo
Adhatoda vasica
Zizyphus mauritiana
Jatropha curca
Rumex hastatus
Zanthoxylum alatum
Ipomoea carnea
Woodfordia fruticosa
Ricinus communis
Eupatorium chinensis

Trees

Melia azaderach
Salix sp.
Acacia catechu
Erythrina suberosa
Dalbergia sissoo
Morus alba

Above 4000 ft (1219m)

Grasses

Dactylis glomerata
Lolium perenne
Eragrostis curvula
Pennisetum purpureum
P. clandestinum

Cynodon plectostachys
Cenchrus ciliaris
C. glaucus
Chrysopogon fulvus

Shrubs

Lonicera quinqulocularis
L. angustifolia
Coriaria nepalensis
Indigofera pulchella
Elaeagnus umbellata

Trees

Salix alba
Populus ciliata
P. nigra
Robinia pseudacacia
Acacia dealbata
Alnus nitida

7. Chos Stabilisation and Training in Siwaliks

Chos, a local word in Siwalik region means "to percolate" denoting that almost all precipitation which is nearly 100 cms/year despite its erratic nature was retained in the catehment leaving very little runoff free of silt. Subsequently, the absorbed rain water comes out or tricles from the ground

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The assistance in the Write-up rendered by Shri S.S. Grewal is gratefully acknowledged.

surface as perennial flow of streams free of silt and streams had regular and well-defined course. Gone are the days, this was the situation when natural cover on the earth sruface was intact due to least biotic interference and there was an equilibrium between vegetation and the environment.

As the population pressure increased, the natural cover was destroyed to clear the land for meeting the needs of food, fuel and fibre. The natural equilibrium was disturbed and land surface lost its canopy. The direct impact of falling rain drops on soft alluvial soils resulted in loosening of top layer which facilitated sheet erosion. Slowly and slowly the rills were formed and changed into gullies which in turn extended their tentacles in all directions and envaded the adjoining fertile lands. The concentrated rain water could find its way easily to rills and gullies without appreciable infiltration and percolation, and these seasonal streams swell up to break and erode their own banks with potential damaging capacity to the adjoining lands. These silt laden seasonal streams are now called 'Chos' with the changed nomenclature.

It is said that during the Anglo-Sikh war, the local Rajas of Punjab sided with Lahore capital and earned ill will of the British. With the political motive, the area was exploited. Poorer the man cheaper is the cost for political bargaining.

The extent of the area unfit for cultivation in Hoshiarpur region in 1859 is 19,282 ha which increased to 1,66,000 ha in 1934. As a result of Choe action between 1884-1897, land value of 1,000 villages decreased by 20 lakhs. Over this was super-imposed impact of high population density, overgrazing and ultimate loss of vegetative cover in the Siwalik region.

Water table which used to be low (15-70 m) because of continuous recharge of ground water has gone down to 170-200 metres. This level is beyond the reach of human exploitation with ordinary means. The infiltration and percolation has drastically decreased because of the removal of top soil and vegetative cover. The physical condition of the land surface has deteriorated due to uneven-ness. There is constant reduction in the fertility and productivity status of the top soil. Today, a sediment yield of 80 tonnes/ha is recorded in the reservoirs from this region, thus reducing its storage capacity. The gullies are increasing in length and breadth.

In the plain lands, sand is deposited which becomes a source of wind erosion. The flood flows of Chos cause repeated damages to roads, railway lines, communication lines and habitations. Due to floods, the lower reaches become water-logged and invite another serious problem of salinity. Cutting and depositing of sand action of Chos pose a constant threat to adjoining fertile lands and lower their safety factor for successful cultivation.

All these factors combined together have put foot brakes to the introduction of modern day technology for the development of agriculture in particular and overall development in general. The statistics can prove the correlation between poor physical condition of the land, water and vegetative resources to the poor socio-economic status of the peasantry.

Recently, in the year 1977, there was extra-ordinary damage by the Choe action in the lower Siwaliks and particularly in the Hoshiarpur area which has invited lot of political attention. These damages have once again refreshed the memory of the Goverment and have drawn its attention towards this much needed programme of Choe Stabilization. The Kandi area development authority has been constituted to implement the scheme of Choe Stabilisation by adopting the integrated approach of Watershed Management. It is represented by the experts of Agriculture/Forest, Soil Conservation, Irrigation and Drainage Departments with the Development Commissioner as the Co-ordinator.

Contro Measures

Control of Chos action can be achieved through works in the catchment areas both the upper catchment called 'Kandi' area and the 'plains'. The catchment in Kandi area comprise of forest lands, agricultural lands and village common lands and pastures. The stream bank erosion control is required in upper catchment and the lower plants as well.

For the integrated development of the catchment areas of the Chos the activities are divided into 3 specific groups as below :

1. Survey and planning
2. Execution :
    a) Forest land by Forest Department;
    b) Village common lands and pastures by Soil Conservation, Co-operative Societies under Department of Co-operatives;
    c) Cultivated lands by Soil Conservation Department;
    d) Stream bank erosion control by Drainage Wing of Irrigation Department.
3. Maintenance : Farming community under active guidance of experts of various disciplines.

The important steps involved and the activities needed have been given in the figure attached, for implementation of the scheme.

For survey and planning, the toposheets of the largest scale available are obtained and forest areas, cultivated areas, etc. of whole catchment are marked alongwith ridge and valley lines, village boundaries, paths, roads and other important physical features. Even the planning work is split up according to the disciplines involved under the guidance of Kandi area development authority having the representatives of the Departments involved. After the planning by each disciplines, they are re-imposed over the original plan and a master plan is prepared for execution.

For execution disciplinewise, the plans and estimates are prepared keeping in view the availability of construction material, machinery, labour force and the finance. The land mortgage banks, commercial banks and Govt. loans are made available for the execution. Suitable amount of subsidies are also provided for works on cultivated lands. Quite recently, World Bank has been persuaded to advance easy and long-term loans. For that model, watershed management plans have been prepared for selected choes like Dholbaha, Janauri and Maili. In these model plans there are provisions for large-size earthen dams to store water and take irrigation channels from both sides to irrigate continuous blocks of land down below. Irrigation Department will construct dams and channels, Soil Conservation Department will make the fields fit to receive irrigation water through underground pipelines and land levelling and bench terracing. Forest Department will ensure the erosion control in forest lands by intensive plantation to reduce the silt load and thus increase the life of the dam itself. The stream bank erosion control mechanical measures such as construction of bunds, vegetation and stone spurs, etc. is carried out by the drainage department. The degraded lands around chos are mostly Panchayat lands which are used for cattle grazing and other allied purposes by the common community. Soil Conservation Co-operative Societies have been formed by the Co-operative Department to take-up the plantation works in these lands.

The execution of works in forest land consists of the following steps :

1) Enclosures from increased human and animal influences of over-exploitatton; 2) Contour/field bunding; 3) Terracing; 4) Contour trenching, 5) Gully plugging and revetment of channel mouth with stones; 6) Easing of slope and planting with species like *Agave*; 7) Landslip control with wattling; 8) Construction of vegetative and masonry check dams and sowing/planting of degraded areas.

Wattling :

On the slope along the contour grass and twigs are bound in long bundles pegged on a narrow log. Small pegs of 60-90 cm in length and 5-8 cm in diameter are fixed and twigs are tied kept in series of 1-2 m apart. The space is filled with soil. Species planted are *Eulaliopsis binata*, *Agave* sp., *Lannea grandis*, Willow and *Vitex negundo*.

Double-line spur :

These are erected along the flow of torrents slightly inclined at 30-45° angle. Length of the spur is 3-6 m. The length is more if it is more acute. 1 m deep and 30-40 cm wide trench is made at a spacement of 1.5 m. In these holes of 15-20 cm diameter and 60 cm deep are made at a spacement of 1.5 m on the same trench in such a way that holes of the two trenches are staggered. In these holes posts of 15-20 cm diameter and 2.5 m length are put of species which sprout. Rest of the gaps are packed with branch cuttings of sprouting native species. To give stability to the post, they are packed with stones, etc. Space between the U shape of branches placed in the trench is filled by brushwood species using *Arundo donax*, *Ipomoea carnea*, *Vitex neguudo*, *Salix* sp., *Bombax ceiba*, *Dalbergia sissoo* and *Cordia myxa*, etc.

A spur is located at the intersection of the Central line of flow and eroding bank across. T of spur no. 1 is double than the length of spur 2. Spur 3 is made at the intersection of the line drawn across the toes of the spur 1 & 2 with the bank. Spur 4 is located at intersection of the line projected across T of the spurs 2 & 3 with the bank. Supplementary spurs are located upstream from spur 1 at the same direction as between spurs 1 & 2.

Spurs are needed to divert flow of water from bank angle. Length and the interspace distance depend upon flood intensity, velocity, strike of water and curve of bank. Generally, spurs are inclined at 15-30° with the bank, the length vary from 3-8 m.

Live hedge run along the bank slightly curved in back. It is smoothened in straight line planting. The works are carried out from outside to the centre of the Choe. Live hedge and spur planting are done in 1 m deep trench. Similarly, during the winter, *Eulaliopsis binata* is planted in 60 × 60 cm to 1.20 × 1.20 cm pits. Afterwards, *Dalbergia sissoo* is planted in 3 m × 3 m trench. Bamboo is a good shelterbelt in Choes in the upper reaches. Silt deposition in the middle of Choe should not be allowed to be formed since it causes obstruction.

The maintenance works are very important for all soil and water conservation measures for increasing their useful life. Special emphasis should be paid to this aspect. Generally, works are executed with Govt. assistance and no funds are provided for future repairs and maintenance. With the result, frequent breaches are caused and works executed with huge money become functionless. Special machinery for maintenance with active collaboration of beneficieries is very important.

Action Programme for Chos Stabilization under different schemes of implementation

Survey and planning	*Execution*	*Maintenance*
a) Prepare master plan of the region-giving extent and boundaries.	Start with I priority water shed from top to below	
b) Collection of all type of relevant data	a) *Forest lands*	1. Enforce forest laws earnestly.
c) Divide the region into watersheds having 2000 to 5000 ha catchment area to act as a unit of planning.	1) Afforestation of suitable economic species. 2) Closure of forests to check human and animals interferences.	2. Regular measures to control forest fires. 3) Annual inspections and repairs of works before rainy season.
d) Find out the priority watersheds depending upon silt load, peak rates of runoff and damages to land and property.	3) Checking of forest fires. 4) Contour trenching. 5) Dry stone/rubble masonry structure. 6) Brush wood structure.	
e) Detailed Soil Survey of each priority planning unit.	7) Checking of lower slide erosion. 8) Stall-feeding.	

f) Detailed topographic maps of each unit.	9) Forest industry-alternate profession. 10) Ponds	
g) Design of treatments in consultation with local population. h) Collaboration with Forest; Soil Conservation; Agriculture; Drainage (Irrigation) and Co-operative Deptt. i) Arrangement of finance and other inputs. j) Landuse boards and authorities-by laws, etc.	b) *Cultivated lands* 1) Land levelling 2) Bench terracing 3) Contour & field bunding 4) Grassed waterways 5) Temporary and permanent erosion control structures. 6) Farm ponds. 7) Diversion channels 8) Agronomic practices for erosion control. 9) Farm Forestry.	1) Fixation of responsibility for repairs & maintenance on farmers fields. 2) Motivation and persuation to own and maintain. 3) Regular checking before rainy season. 4) Adequate provisions of funds and materials for repairs.
	c) *Pasture lands & other village common lands* 1) Land preparation 2) Making blocks 3) Introduction of suitable grasses. 4) Moisture conservation treatments. 5) Controlled/deferred grazing. 6) Good breed animals	1) Active participation of Panchayats for joint repairs and maintenance of pastures. 2) Regular programme of cutting, feeding on scientific lines.
	d) *Stream bank erosion control* 1) Construction of earthen bunds on both sides of the	1) Bunds breach in first few years; plugging and breaches after

chos for reclaiming extra land for the bed.

2) Planting in staggered manner Sarkandas on slopes of bund.
3) Construction of brush wood spurs at turns and beds.
4) Construction of vegetative spurs.
5) Plantations on stabilised terraces on both sides.
6) Constuction of drystone spurs and wire crates at turns and beds.
7) Wattling.
8) Jetties.

rains.

2) Precautions against rats and rodents damage to bunds.
3) Regular maintenance of ramps and causeways.
4) White ants damage the brush wood poles which should be coal-tared and checked regularly.

During later half of the 19th century, uncontrolled grazing and browsing destroyed the forest and soil cover of the hills, rain water instead of being absorbed in the soil poured down the hills with greater velocity and brush bringing all the erodible soil of the hills. Thus, the rapidity of storm water increased and sand laden torrents which poured down the steep ravines and vallies become extremely violent. This is how the Chos spread from the Siwaliks down to plains. In the hill slopes also carrying capacity of water increases and the flood carries much material in suspension in which small boulders and stones are transported. After issuing from the confines an easier gradient is encountered, velocity of water is reduced and the heavier material in suspension is deposited. The chos spread outright and left to form expanses of sand. These play havoc during monsoons. They are means to carry tonnes and tonnes of unwanted sand and silt to the lakes and reservoirs.

The over-hanging hillocks cause havoc to contribute silt since the flowing water moistens the base of these earthen walls. Live hedge spurs could check the falling of vertical soil cuts which act as combs for the stream water and make it deposit the silt behind them. Some of the species are Kana, Shisham and Kikar. At all bends, such spurs are constructed. After the stream comes out of the confines of hills chos spread out on both sides as expanses of sand. It is here that intensive chos training is required by a series of live hedges and vegetative spurs.

Hills torrent and Stream-bank erosion control : Hill streams are characterised by wide spreading bed, ill-defined banks, flashy flows and swift currents. These are ephemeral flowing only during the rainy season when they get swollen up with floods during high intensity rains in the catchment areas above. The sudden and violent flows cause movement of large detritus comprising of boulders, shingle, sand and silt depending upon the terrain geology. This detritus raised the bed of the river thus reducing the flood carrying capacity of the torrent resulting in over-flows, meandering of the course of flow and erosion of the banks. These torrents render vast agriculture areas unproductive by under-scouring and deposition of boulders, shingles and sand over them. Roads sometimes get breached, lines of communication broken, bridges are chocked and washed away, wells and irrigation channels get filled-up with detritus, water supply is disrupted and river gets charged with heavy sediment load resulting in siltation of reservoirs.

Torrent training works are aimed to channelise flow of water and reclaim rest of area under bed and sides for protection of agricultural fields, roads and habitation from destructive action of floods. This is achieved by bank consolidation through planting of live hedges and strips of grasses, shrubs, trees and deflecting the main current away from the bank by erecting spurs and other suitable structures. In the hilly areas, where bed gradient is steep, torrent control aims further to check deepening of torrent gorge or channel bed thus reducing the phenomenon of undercutting of banks and transportation of sediment to lower reaches in foothills. This is achieved by constructing sediment detention dams and afforestation of the catchment areas.

The torrent training works comprise combination of various vegetative and engineering measures such as 1) Retards, 2) Revetments, 3) Spurs and 4) Grade stabilization. Along the eroding bank of a torrent with stable gradient the retards are erected in order to retard stream velocities and to prevent erosion of bank or scour of its toe.

The purpose of Streambank Erosion Control is to control bank cuttings in order to protect valuable adjoining land and to reduce the silt load of the stream. Thus, control is mainly through the use of vegetation supplemented by mechanical installations to ensure satisfactory establishment of vegetation. The work done on any segment will be affected by the condition of the stream above and below the segment being considered. Therefore, it is advisable to protect the entire length of stream in a phased manner. Behaviour of streams at flood stage or near flood stage is often unpredictable. This makes it advisable to aviod jobs of large-size unless good engineering data is available such as size of watershed draining into stream, expected run-off and flood peak, expected debris load, causes of existing meandering and erosion such as may be fallen trees deflecting water from its normal flow direction, trees or brush growing on inside of a curve deflecting water against cutting bank, water from a waterway or smaller stream entering the channel and depositing sediment, thus deflecting water against cutting bank.

Among treatments, most of streambank protection can be accomplished by the establishment of a suitable type of vegetation. It may be necessary to protect the vegetation during establishment by mechanical means such as stakes, mats, piles or rock jetties according to prevalent conditions.

General treatments :

1. *Protection from livestock*: Livestock for watering should not be allowed to cross steep banks.
2. Correction of causes of meandering by removing fallen trees, removal of bushes on inside curves or

eliminating sediment carried by waterways and small streams.

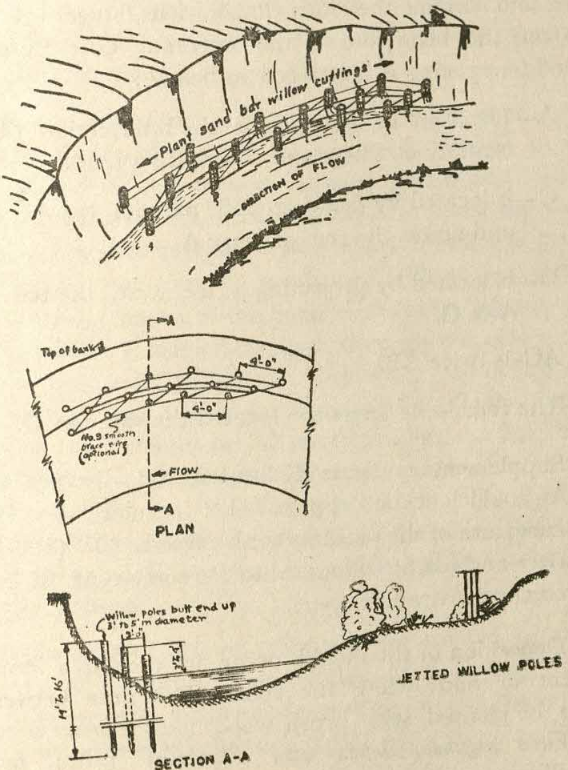
Mechanicat control :

1. *Felled poles for stream protection* : For medium-sized streams with ballies not more than 2.5—3m high and with watersheds 5-15-10 sq Km apart from protection from grazing on the cutting side willow poles (self-sprouting sp.) are driven or jetted. Above the normal waterline in a double row with the poles 60–120cms apart and staggered between rows. Poles 2-3m long, 7-12cms in diameter. About 2/3rd should be below ground-line. Sharp curves or higher banks need supplementary and rock wing dam.

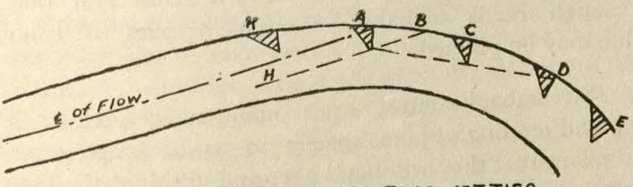
2. *Piling jetties* : Construction of a deflecting jetty is favoured where streams are more than 4m wide with banks of over 3m.

Spacing of jetties : The spur should slope towards the down-stream and to produce the desired effect of deflecting the stream away from eroding bank and depositing silt behind the spur. In general, the spur should not be right angles to the bank. A good rule to follow is to place the jetty at the angle which will give the maximum deflection of the current without setting-up damaging eddies at either end of the protective work. Consideration must be given to the amount of restriction of the channel that can be allowed taking into account the proximity of the opposite bank and the prospects of scouring a new channel without placing too high a head of water against the structure. If the opposite side of the stream consists of a high bank which cannot function as a flood plain, there is little chance of the protective work being successful. In other words, where velocities cannot be reduced by the spreading of the flood waters, stream bank protection between opposite high banks should not be attempted.

Due to the variation in conditions such as degree of curvature of eroding bank, changes in velocity and quantity of discharge, soil types, width of stream, property to be protected, it is difficult to formulate a thumb rule for spacing of


Plant sand bar willow cuttings
DIRECTION OF FLOW
Top of bank
4'-0"
4'-0"
No. 9 smooth brace wire (optional)
Flow
A
A
PLAN
Willow poles butt end up 3' to 5' in diameter
2'-0"
1' to 4'
14' to 16'
SECTION A-A

JETTED WILLOW POLES



METHOD OF LOCATING JETTIES

spurs. The observation made on the flow of water past a completed upper spur will help locate the next structure below, taking into account the effect that various stages of flow may have on the behaviour of the current. One "tnump rule" method for spacing is illustrated as below :

A—Location of Ist spur is the intersection of the first centreline of flow and the eroding land.

C—is located by drawing HB parallel to the flow line and across the toe of Jetty A.

D—is located by projecting a line across the toe of spurs A & C.

AC–is twice AB.

The remaining spurs are located the same as D.

Supplementary spurs K located AC distance upstream from A should not be approx. 1/2 regular size. Generally when curvature of the eroding bank exceeds 30° (190′ radius), it is safeer and more economical to use some type of revetment for protection instead of spurs.

Deposition of silt should occur in the area immediately adjacent to and below the spur. The area between spurs should be planted with brush wood like *Ipomoea carnea*, *Salix* sp., *Vitex negundo*, *Bobax ceiba Erythrina indica*, preferably with self-sprouting species and protected from grazing. Suitable planting can also be made between banks and the fence. If enough area is available, economic species of commercial value may be planted.

Streambank control require maintenance such as i) pruning and tending of plant species so as to keep stems small and pliant that they will bend over and "shingle'' the streambank during periods of high water; ii) trees planted for bank protection should always be cut out before they reach 5 cm in diameter; iii) Debris lodged against banks during floods should be removed immediately afterwards; and iv) brush growing on inside curves should be cut down periodically.

3. *Jacks* : This method can easily be adopted by local populace and consists of placing one or more rows of jacks along the stream bank. These are constructed by cutting three poles of 2.5-3 m in length, depending on the depth of stream to be controlled (Multiply depth of stream × 1.4 to determine length of poles required).

These are closed and wire together at the mid points. The ends are then tied together as shown in figure. A series of jacks is placed in the stream enough to protect the area where cutting occurs. These are spaced as close together as possible with not over one jack space apart. This will provide an almost continuous line of revetment. These are kept in place by tying the centre of the jack with cable clamps to a main cable which is carried around through the centre of the jacks on the area to be protected. The upper end of this cable is tied to a dead man, which in turn anchors all the jacks as a unit. The cable should be 1-2 cm depending on length and depth of stream. The dead man should consist of a 2 m long timber about 20-25 cm in diameter. Each jack should be weighted by rock which can be wired into the poles. Reinforced concrete posts or angle irons can be substituted for poles in the jacks for permanence.

Straightening of stream channels for control of stream bank erosion should rarely be undertaken as it is very expensive and may result in further bank cutting due to the increase in grade of the shortened ehannel.

8. Plantation to save Beach Erosion

An old sailor's saying has if that 'The Sea goes where the Sea wants to go and no man can stop it'. Men have tried to stem the tides for centuries, sometimes with the success of the Dutch and sometimes with all failures of King Cannte. Recent studies have shown that the problem could be solved by redirecting the beach system by introducing sand to change its off-shore profile. It has been found that Cuspisthe rhythmic hills and valleys of sand along a beach edge are caused by reflective waves which travel along the beach. On small beaches, these waves do little harm but on long beaches, they cause serious erosion. This type of wave could be eliminated by changing the offshore profile of the beach by dumping quantities of sand at the right place. Once the ability of this edge wall to occur is eliminated, it is possible to push the beach into an entirely different regime-so that it will mantain the new regime and stabilise it. Beaches also stabilise themselves by taking sand from nearby dunes but back waters and coastal high rise buildings have prevented this.

Among the important grasses which could be used on sea beach to stabilise coastal sand *Spinfex squarrosus* stands out most prominent alongwith *Aeluropus lagopoides*, *Dichanthium annulatum*, etc.

Other sand-binding plants are *Barringtonia racemosa*, *Calotropis gigantea*, *Canavalea obtusifolia*, *Cassia auriculata*, *Ipomoea biloba*, *Pandanus odoratissima*, *Scaveola konigii*, *Tamarix gallica* *Tephrosia* sp., *Turnera ulmifolea*, and *Vinca rosea*.

Ornamental and useful trees and shrubs for coastal areas are *Acacia leucophloea*, *A. planifrons*, *A. nilotica*, *Adansonia digitata*, *Albizia lebbek*, *A. odoratissima*, *Azadirachta indica*, *Barringtonia speciosa*, *B. racemosa*, *Bauhinia tomentosa*, *Berrya ammonilla*, *Borassus flabellifer*, *Caesalpinia coriaria*, *Carallia integerrima*, *Cassia fistula*, *C. marginata*, *C. multijuga*, *Casuarina equisetifolia*, *Cerbera odollam*, *Cochlospermum gossypium*, *Calophyllum inophyllum*, *Cocos nucifera*, *Delonix regia*, *Diospyros embryopteris*, *Dodonaea viscosa*, *Duranta plumeri*, *Eucalyptus alba*, *E. citriodora*, *E. calophylla*, *Ficus benjamina*, *Holoptelea integrifolia*, *Leucaena leucocephala*, *Millingtonia hortensis*, *Miscodon zeylanicus*, *Murraya exotica* var. *buxifolia*, *Moringa pterygosperma*, *Peltophorum ferrugineum*, *Pandanus tectorius*, *Persia semecarpifolia*, *Pisonia alba*, *Pithecolobium saman*, *P. dulce*, *Plumeria acutifolia*, *Polyalthia longifolia*, *Spathodea campanulata*, *Swietenia mahagoni*, *Tamarindus indica*, *Thespesia populnea*, *Vitex altissima* and *V. leucoxylon*.

Ornamental shrubs and climbers :

Acalypha sp., *Agave americana*, *A. variegata*, *Arundo-donax variegata*, *Asystasia coromandeliana*, *Caesalpinia pulcherrima*, *Carissa carandas*, *Clerodendron inerme*, *Nerium iudicum*, *Thevetia peruviana*, *Allamanda hendersoni*, *Antigononi leptopus*, *Argyreia speciosa*, *Bignonia* *unguis*, *Bougainvilla spectabilis*, *Ipomoea bonanox*, *I. muricata*, *I. briggsii*, *I. carnea*, *Porana volubilis*, *Quisqualis indica*, *Tecoma capensis*, *Thunbergia grandiflora*, *Tristellaria australis*.

9. Reclamation of Lands subjected to Shifting Cultivation

Jhuming, as it is known in North-eastern region, is regarded as a first step in the transition from food gathering or hunting to food production. The system is believed to have originated in the neolithic period around 7000 BC. (Sharma 1976). Shifting Cultivation practices are followed in the states of Bihar, Andhra Pardesh, Maharashtra, Kerala, Karnataka, Madhya Pradesh, Tamil Nadu, and throughout the hill states in Eastern Himalayan region (Assam, Mizoram, Manipur, Maghalaya, Nagaland, Tripura, Arunachal etc.). It is reported that about 2,07287 hactares are affected in Assam, 46,964 hactares in Tripura and 21,862 hactares in Manipur. About one fifth of the total land surface in Orissa (3,308502 hactares) alone is affected by Shifting Cultivation (Mooney 1951). National Commission on Agriculture (Pt. IX on Forestry) estimated 4,92,000 tribal families to be involved in *Jhuming*. It is also estimated that nearly one million of tribal people depend on method of this raising crops in Orissa state only for their livelihood. Total area affected by *Jhuming* is 26,94,000 ha while 4,53,C00 ha remain under *Jhuming* at anytime. This form of impermanent land husbandry is variously known as *Rama* by the Kondhs, *Bringa* by the Buuyans in North Orissa and as *Podu*, *Gudia* and *Dongar Chas* in the South.

The system essentially consists of i) selection of site (December-January) leaving a patch of forest on steep slopes; ii) burning the natural vegetation during the months of mid February to May. The felled material is allowed to dry-up and is burnt. The ash thus obtained is spread over the soil; iii) the soil is either ploughed when the slope is moderate or worked by manual labour when the slope is steeper and seeds are dibbled. In some places, the seeds are sown on the upper half of the cleared slopes allowing the seeds to be carried down by rains and distributed all the lower slopes; iv) mixed-cropping pattern is followed and seeds of eereal millets like Maize, Sorghum, Ragi (*Eleusine coracana*), *Panicum miliaceum* and hill paddy are sown with legumes such as Arhar (*Cajanus cajan*), Urad (*Phaseolus* sp.), Danger rani (a sort of Cowpea) and Beans (Buta bean and Creeper bean). Seeds of other species sown are of Niger (*Guitzotia abyssinica*), Castor oil (*Ricinus communis*), Til (*Seasamum indicum*), Cucurbits, etc. The crops are harvested between September and November except the Pigeon pea which is harvested in late part of winter; v) abandoning of land after cultivation for 2 years and shifting to another site; and vi) return to same site to repeat the process.

It seems that such a practice is a part of their life rather than an occupation since the yields are hardly sufficient for the tribal's own needs. The food is usually supplemented with wild plants like Dioscoreas, Jackfruit (*Artocarpus* fruit and seeds) *Tamarind* (seeds), *Curcuma* (rhizome), *Mangifera indica* (Fruit) etc. Each tribal is reported to be wedded to a tree of *Caryota urens* for their drinks in Orissa. Their income is supplemented with certain plant-based industries like brooms (from *Thysanolaena agrostis* and *Aristida cynantha*), mats and baskets (from bamboos) ete. which are brought to the weekly markets and exchanged for salt, jaggery, cloth, etc. The tribal co-operative societies help them to sell their produce in these areas.

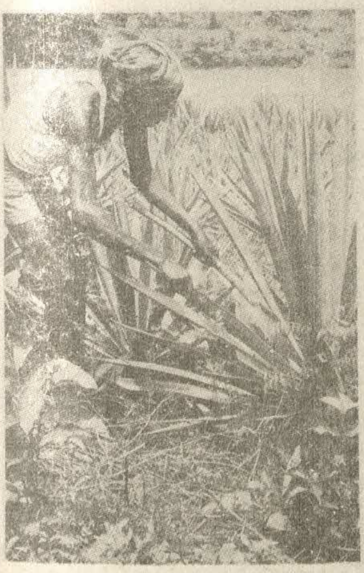
The rapid exhaustion of soil fertility from the areas cultivated by tribals is experienced because of too steep hill slopes and absence of any soil and moisture conservation practices. This forces the tribal cultivators to abandon these sites after taking two crops in successive years. The cultivators subsequently search for new areas and do not return to the areas first cleared for sometime. Thus, the rest period given to land for regeneration of vegetation and soil fertility is considerably reduced from eight to twelve years in some regions of Orissa and 3-6 years in Eastern Himalaya. This period used to be longer (twenty to thirty years) and has been reduced considerably to increased pressure on land. Density of population in Shifting Cultivation Zone varies: Jantia & Khasi hills 66, Naga hills 49, Lushai 24, Garo 6, Koraput 129, Kalahaidi 160, Phulbani 107 per 1.6 Km

These areas have created Soil and Water Conservation problems since these are associated with heavy rainfall (150 cm in Orissa to 175-150 cm in E. India), thus causing large-scale displacement of soil particles with heavy rains and increased water velocity and runoff. Frequent incidence of bush clearing and shifting cultivation have resulted in low crop yields associated with accelerated soil erosion. The hill slopes over large areas have been affected by the water regime with the result that frequent floods occur during heavy rains. Springs which were once perennial remain dry in summer. Heavy silt is brought down with high intensity rains and either deposited in adjoining crop fields making fertile areas unproductive or flow down through gullies to drainage channels and to rivers and reservoirs. The rivers thus show more meandering due to rise in their bed and are prone to floods during rainy season. The best utilization of the Valley lands has been made in Orissa by terracing the fields in the drainage channels and utilizing the water for paddy cultivation. The uplands are primarily cultivated for growing crops like Turmeric which is sown during the months of April and May in patches. Heavy mulch of Sal leaf litter is provided after sowing. The occasional and intermittent premonsoon showers help in germination of this crop which is harvested during November-December.

The chief strategy for the development of this region seems to be rational landuse in the watershed, depending upon the land capability. Alteration of agriculture with Silviculture and Horticulture play an important role in protecting the soil in this region. The watershed approach is essential since the effects of shifting cultivation are for reaching and the entire tract is affected. However, involvement of people 'by conversion and not by coercion' will do much to rationalise shifting cultivation to settled agriculture. Though presently economic species such as *Anacardium occidentale* (Cashew nut), *Acacia auriculaeformis*, *Eucalyptus hybrid*, *Pinus khasya* have been planted on a large-scale, species useful to tribal community need more emphasis. It is suggested that frequent use of species like *Mangifera indica* (Stone planting with grafted in situ), *Emblica officinalis* (grafted in situ), *Artocarpus integrifolia* (Jackfruit), *Caryota urens* (Palm locally used by tribals for liquor), *Dendrocalamus strictus* (Bamboo), *Bassia latifolia* (Mahua), *Tamarindus indica* and other species of local use should be made during the afforestation programme in the hill slopes in order to win over the people and provide raw material for plant-based industries. Use of *Agave sisalana* on denuded hill slopes and Sisal fibre extraction by Soil Conservation Organisation is commendable. The broom grass (*Thysanolaena agrostis*, *Aristida cynantha*) provide a good scope for planting in the area of Orissa state. Conservation Farming on uplands and Jhoola (valleys) is needed with Soil Conservation practises on large-scale for higher productivity. Though this has been practised by Soil Conservation Organization in some parts of Orissa and Assam states, wider application of stone terracing and bunding programmes are needed where bunds should be protected with some perennial palatable grass. Follow-up and maintenance of these structures is very much desired. Model of a landuse plan is provided in the table for region affected in tribal areas of Orissa, Madhya Pradesh and Andhra Pradesh.

Land class	*Recommended use*
1. Nala beds (bottom land and field terraces.	Intensive agriculture through use of HYV, fertilizers, crop rotation and water management practices.
2. Lands 5-10° slope	Agriculture on contours or graded stone terraces.
3. Lands with less than 20° slope	
i) With sufficient soil depth	1. Silvi-Horti.-pastoral uses. Stone terraces for cultivation.
ii) Where suffcient soil depth is not available	2. Under permanent vegetation such as fruit farming and pasture development.
4. Lands with less than 20° and more than 10° slops.	Plantation of Cashew nut, *Tamarind*, Jackfruit, *Agave* and other trees of economic impor-
5. Lands with more than 20° slope.	1) Forestry plantations of *Acacia auriculaeformis*, *Tamatind*, *Eucalyptus* sp., *Pinus khasia* etc.

HYV=High Yielding Varieties



Harvesting of Agave leaves commence after 3-4 years of planting. At a time 10-12 leaves forming an ∟ of 45° from the plant are harvested leaving upper vertical 10 leaves on the plant.

The leaves of Agave are bundled and transported for fibre extraction.

For convenience the serrated margins of the leaves are removed. Each leaf after decortication gives about 6 gm of dry fibre. Presently the fibre is sold @ Rs. 550/- per quintal

Plants associated with tribals food need be encouraged in plantations. Fruit plants are protected by tribals themselves while clearing vegetation.

2) Enclosures for natural regeneration. Protection of hill slops above 10° lead to regeneration of local grasses.

Though efforts have been made to settle the tribals, experience has shown that the tribals have a preference for Shifting Cultivation and there is reluctance on the part of the tribals to use the plough and cattle for land tilling. Lack of the monetory economy and their ignorance towards settled agriculture has to be taken into consideration apart from their own way of life before any attempt is made to settle the tribals. Proper socio-economic surveys of their attitudes, habits, customs, etc. are required before development plans are initated to discourage this menace of Shifting Cultivation. Chaturvedi and Uppal's (1953) observation in Assam are important which are as reproduced below :

"The correct approach to the problems of Shifting Cultivation lies in accepting it not as a necessary evil, but recognising it as a way of life, not condemning it as an evil practise but regarding it as an agriculture practice evolved as a reflex to physiographical character of land. For too long, Jhuming has been condemned out of hand as a curse to be ashamed of a vandalism to be decried. This attitude endangers an inferiority complex and an unhealthy atmosphere for the launching of any development scheme seeking to improve the current practises." In its ultimate analysis, the problem resolves itself into devising ways and means 1) for utilising the fertility of the soil in full and 2) for restoring the fertility when exhausted.

Schlippe (1956) observed in Africa that "the modern civilization has failed to improve African agriculture because it has proved so far incompatible with the environment of the wet tropics.......Agriculture is that sector of human activity in which there is greatest interaction between the environment and the human culture which has grown in and from it". He therefore, advocated "to find improvement without doing violence to the limiting framework of tradition and environment".

Majumdar (1971) feels that Shifting Cultivation in the North-eastern region cannot be avoided for a long time and hence concentious efforts are needed to improve productivity of Jhum cultivation and minimise soil erosion. While doing so, he advocates that 'an important aspect duly recognised as a crucial study for development is the need to tailor the programmes to the local conditions and values".

So far, the problem has been the subject of study primarily by anthropologists and economists. An integrated approach involving both social, biological and physical scientists is, therefore, needed. Since 1975, apart from the Soil Conservation Departments of the State Govt., an ICAR Research Complex for NE Hill Region is working on this problem in greater detail. The data recorded (1978) is interesting. Studies on Soil loss, runoff and crop productivity under four farming systems viz. Jhuming, partial (1/3rd at base) terracing, complete bench terracing and Puertorican terraces showed maximum runoff (5.3%) and soil loss (40.9) t/ha) under Jhuming while under 1/3rd terracing, complete bench terracing and Puertorican terracing, it is respectively 3.9, 1.5, 12.9 and 5.8, 4.0 and 39.3 t/ha. Regarding crop yields, it has been shown that total yield of crops from 1/3rd terraced area is much higher than from the whole area under Jhum. The approach to treat one third of the area under Shifting Cultivation for economy reasons has to be followed with care, keeping in view its socio-economic impacts on land, water, soil and the tribal population.

10. Foreshore Area Afforestation*

The various reservoirs constructed such as Tungbhadra, Govindsagar and in Damodar Valley are planted with vegetation in order to reduce silting in the reservoirs. Even today invariably near village tanks planting is seen which reduces silting in tanks and minimize evaporation losses by reducing wind speed.

Techniques followed for such foreshore plantation consist of Trench mound plantation. Continuous contour trenches are practised near Tungbhadra dam reservoir. Size of the trench is 4m × ½m × ½m. Sowing is done both in trenches and mounds. Planting of seedlings is done in the half filled trenches @ 3-4 seedlings per trench. Foreshore area falling between contours 544m (1633′) and 545m (1635′) is to be tackled by trench mound plantation. Trenches are oriented (16½′) 5.5 m apart row to row; old spacement of 11m (33′) has been given up. Among the species planted in the trench are Mysore gum (*Eucalyptus hydrid*), *Dalbergia sissoo*, *Albizia amara* and *Pongamia glabra* while species sown in the trench and on the berm are *Acacia nilotica*, *Cassia siamea*, *C. auriculata*, *Hardwickia binata* and Palmyra palm (*Borassus flabellifer*). Sowings of Palmyra failed in many places while that of *Acacia nilotica* did not succeed near the lower contours primarily due to tidal action, inundation and uncontrolled browsing damage. Similarly at other places, *Hardwickia binata* did not succeed while *Eucalyptus hybrid* showed encouraging growth.

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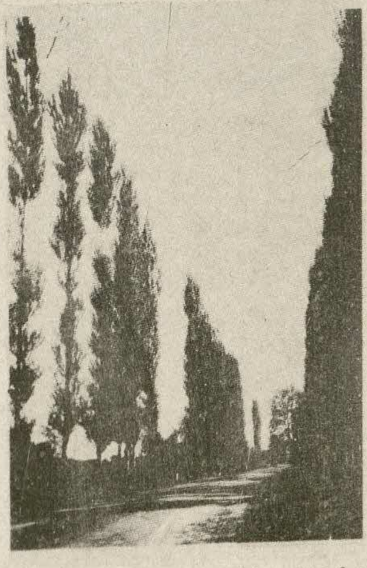
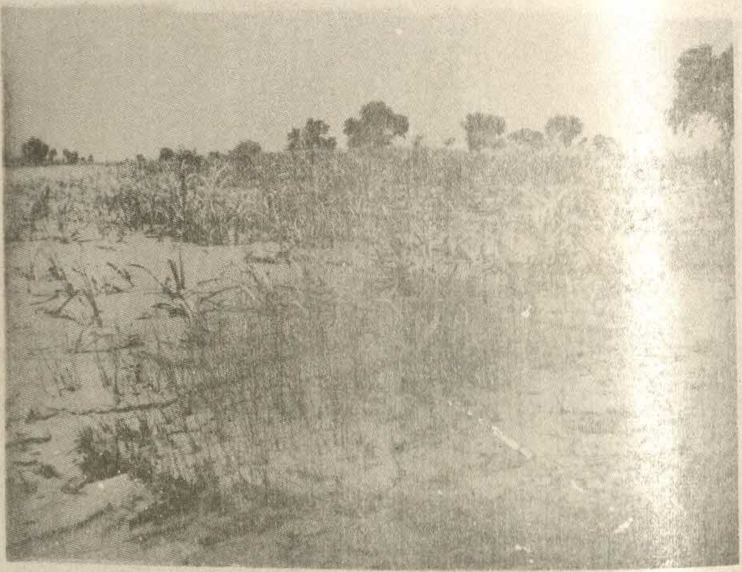
*Help from Sri R. Subbayan, in collection of data is gratefully acknowledged.

Management of these forests has not yet been prescribed though looking to the growth of *Eucalyptus* a 10 year rotation seems to be reasonable where'in an yield of 20-25 tonnes/acre is expected. In many of such plantations, no thinning has been done. *Prosopis juliflora* sown on the periphery does interfere with growth of valuable species like *Eucalyptus*. Such periodical thinnings would be beneficial to the plantations. Practically no ground cover of shrubs and grasses could be seen due to grazing though such areas need to be opened up for grazing after 5 years of closure. Growth of a 7 year old plantation of *Acacia nilotica* and *E. hybrid* is respectively 6-8 and 8-10 m while a 10 year old plantation reach 12-15 m height. Average girth at breast ht. is 40 cm. At places due to inundation and water stagnation, plants like *Dichanthium caricosum* and *Typha* invade while *E. hybrid* show discolaration due to continued inundation at the root zone. These areas are often ploughed and cultivated but such agricultural operations are not to be encouraged to avoid sedimentation in the reservoirs.

Gond tribals clear natural vegetation for land preparation to shifting cultivation.

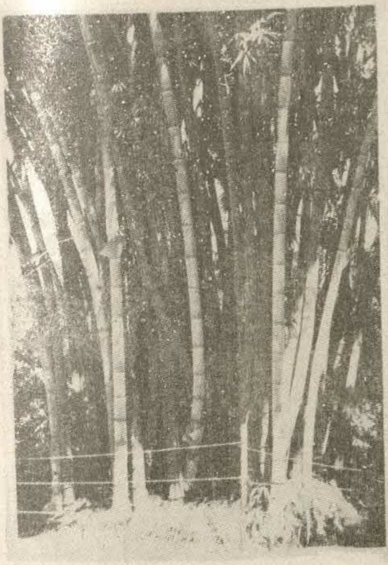


In temperate regions on roadsides and on farms Poplars provide a wide spectrum of species. Photo shows poplar used on roadsides in Srinagar valley.



Crop damage as a result of flooding.
(Courtesy Punjab Govt.)

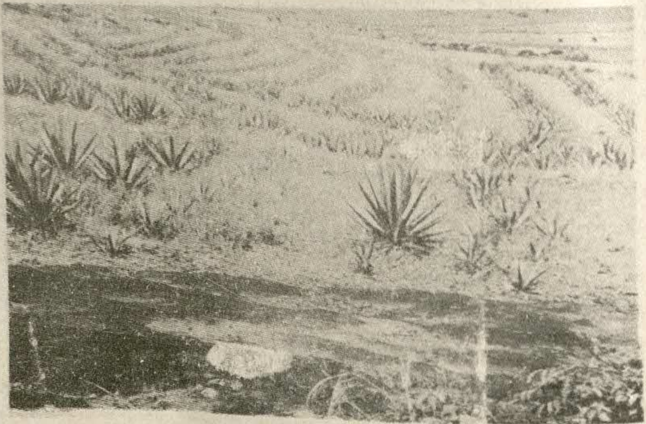
Floods cause heavy damage to crops and bring misery and dislocation to millions. (Courtesy Punjab Govt)



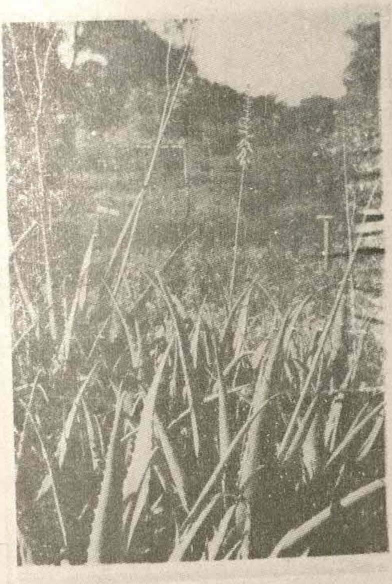
Bambusa arundinacea and other Bamboos provide raw material for rural cottage industries apart from checking soil erosion.

Nerium indicum (Vern. Kaner) is a hardy shrub used in gardens and for soil conservation.

Parkinsonia aculeata on canalsides in Haryana.

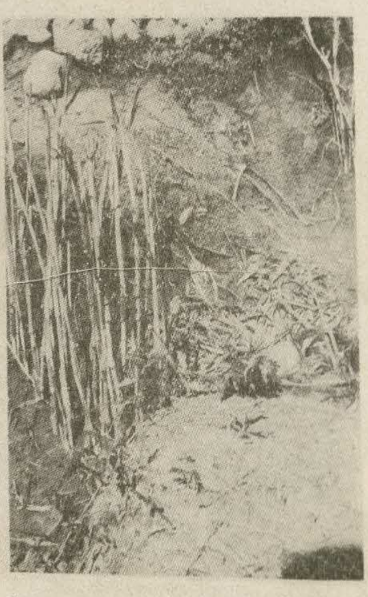


Agave sisalana a suitable species for hill slopes both for **soil conservation and fibre.** It is planted in pits 0.3 m³ on **slopes along the contours** at a distance of 1 m plant to plant **staggered in 2 rows** Distance from row to row being 60 **cm, while internal spacing** is 2-3 m. On acidic soils lime **@ 1 ton/acre is added with NPK** mix. 3500-4000 plants **are planted in an acre** generally.



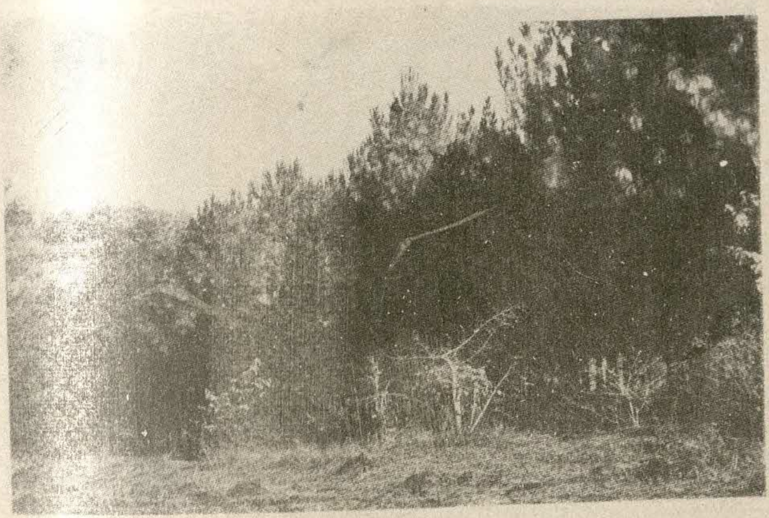
Aloe vera – a plant which has medicinal properties is grown near cemetries.

Foreshore plantation of Eucalyptus hybrid near Tungbhadra reservoir provide fuel, check siltation of reservoir and reduce evaporation losses from water body. (Photo Courtesy R. Subbayan)

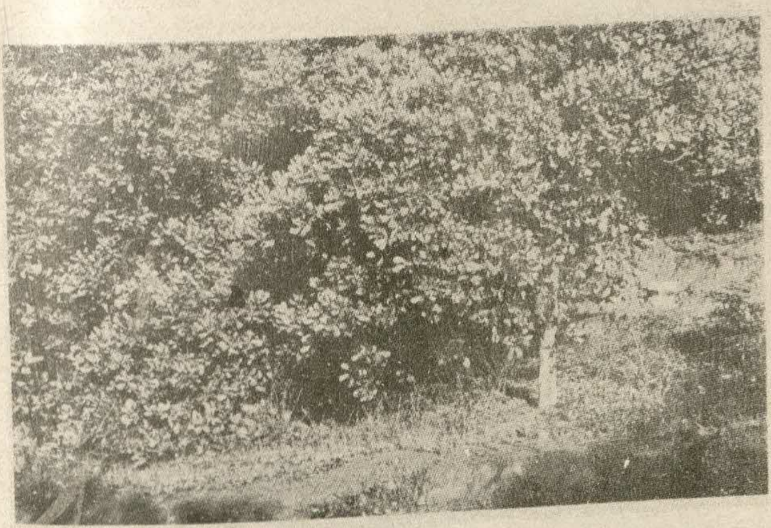


Grasses such as Napier and Arundo donax form vegetative barriers for terracing and gully plugging.

Morus alba commonly known as Mulberry provides leaves for fodder and sericulture, branches for baskets and wood for fuel needs encouragement on farms for agro-forestry

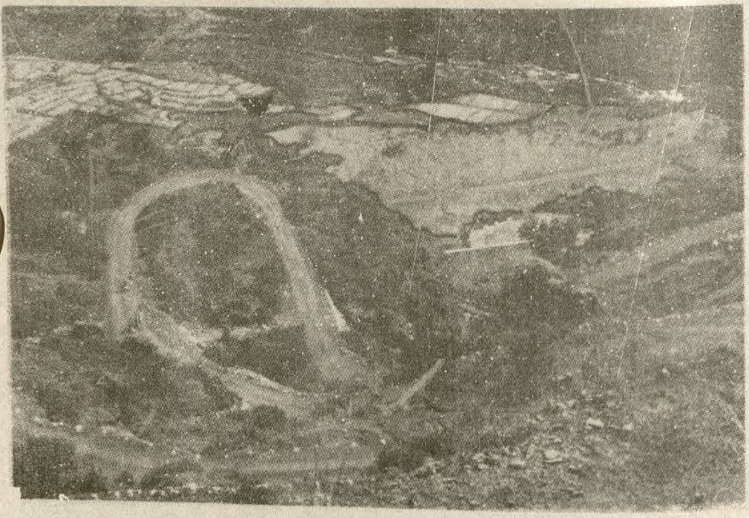


Pinus Khasya is most favoured as the tropical pine on hills denuded by shifting cultivation practises.

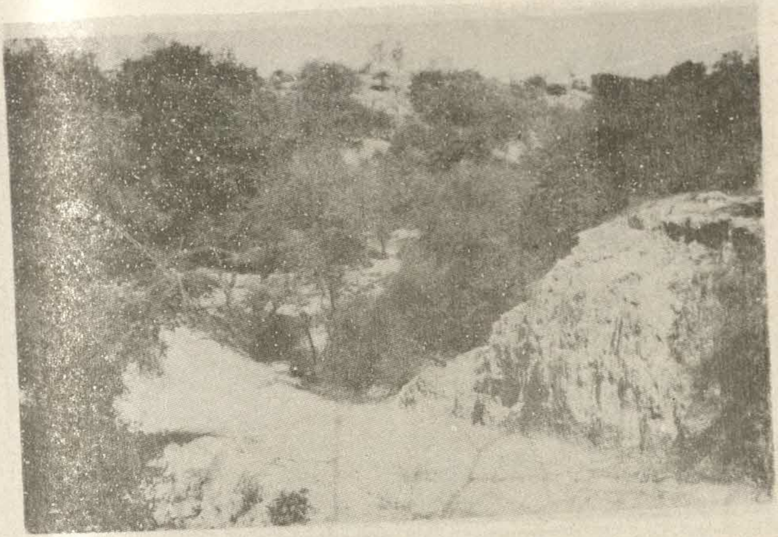


Cashew plantations on denuded hill slopes provide both protection and cash in Orissa.

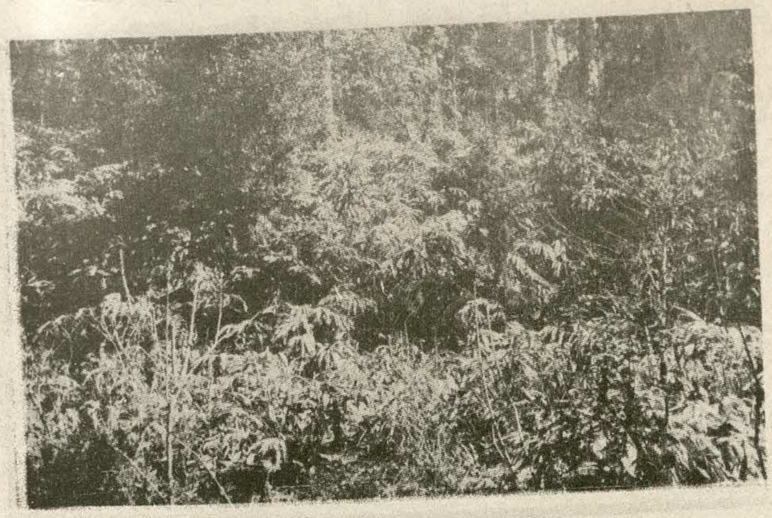
Outer hill slopes of Himalayas are subjected to erosion by limestone quarrying.



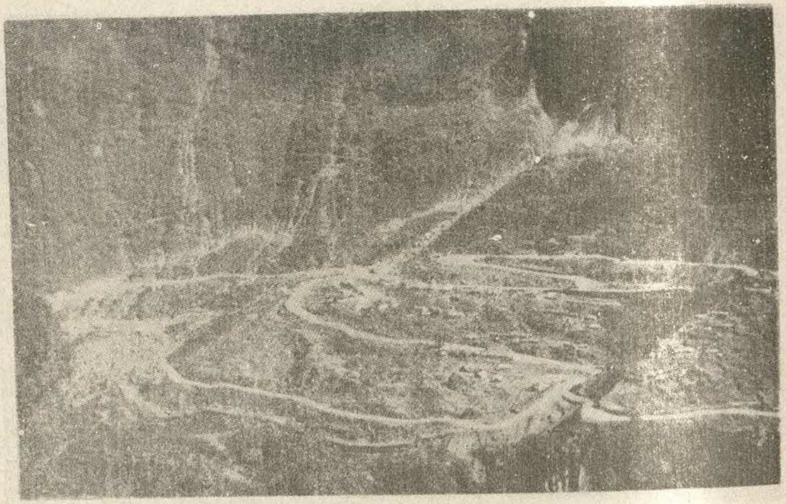
Rock phosphate mining in the outer hill regions pose problems for both slope stabilisation, silt transport and deposition on cultivated fields and water pollution.



Stabilisation of gullied lands near Agra with Prosopis juliflora, and Acacia nilotica ssp. indica.

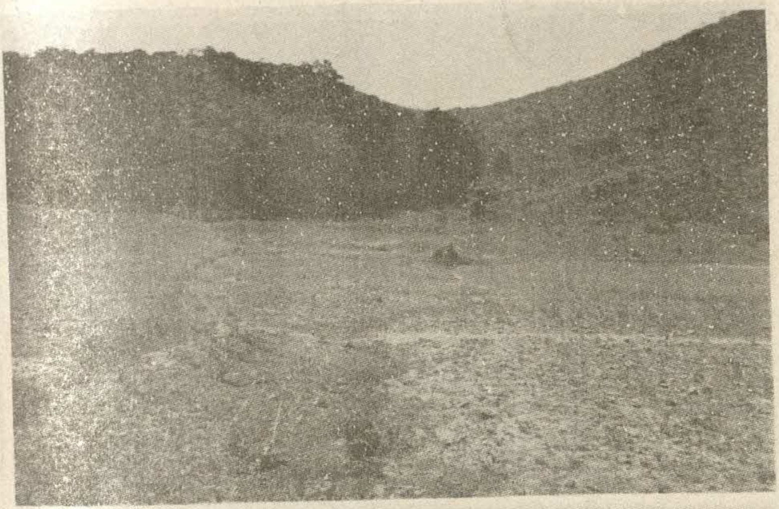


Cardamom and other plantation crops are favourite in Sikkim and tribal belt of Orissa. Photo shows plantation raised as understorey in forest leased by Forest Deptt.

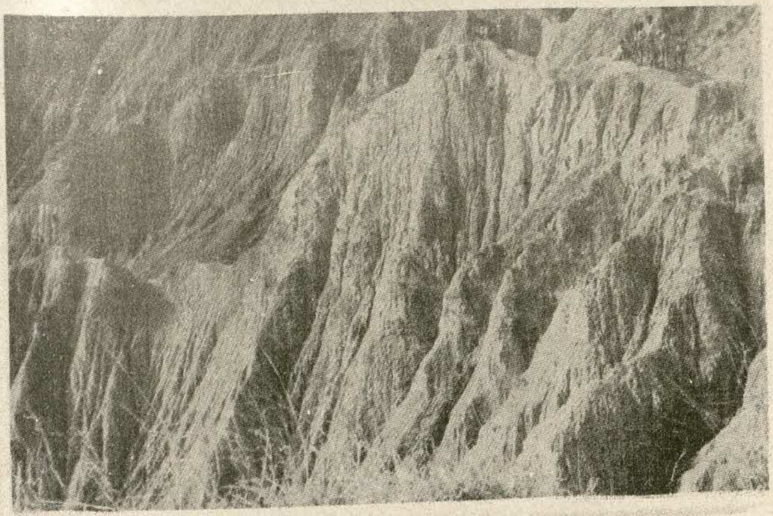


Frequent landslips pose problems in keeping roads open. Photo shows various roads alignments made to avoid landslips in Sikkim.

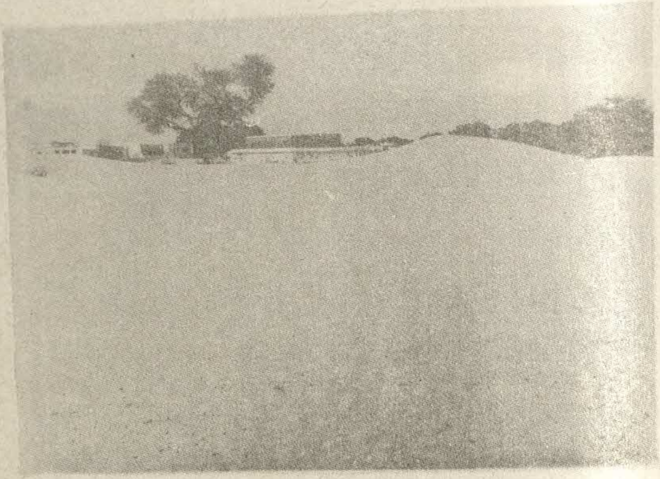
Eucalyptus is the most favoured species for roadsides in Haryana and Punjab. These strip forests produce about 7 tons of fuel wood per hectare with a rotation cycle of 7 years apart from providing shade.



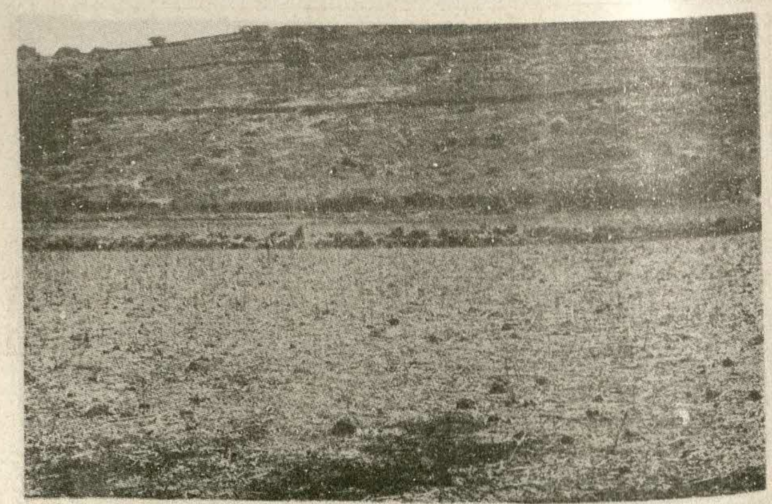
Acacia auriculaeformis plantation on hillslopes provide fuel in Bihar and Orissa.



Siwaliks are prone to soil erosion. Photo shows severe erosion taking place in Siwaliks.



Sand encroaching habitations at Satnale in Mahendragarh District



Hillslope with stone terraces stop sliding and used while afforestation.

For Casuarina plantations protection from wind is provided by erecting artificial barricades on sea shore plantations.

Casuarina plantations as shelterbelt for afforestation of coastal sand dunes

Flooding cause damage both to soil and crops. Wattling a common practise to break slopes before any stabilisation work is attempted.

Alnus nepalensis planted on riversides all over the Himalaya can check floods and provide fuel

Plantation on Farmland

Bulk of the rural population has been getting their requirement for firewood and small timber from tree growth on farm and community land and partly from protected and reserve forests. This is continuously rising with the growth of population. Since villagers have rights and previlages in reserved forest near habitations steps to provide fuel and wood from new plantation on farmland will spare the reserve areas primarily for production forestry such as timber and raw materials for industry. It has been definitely concluded that fuel wood would be the main source for non-commercial fuels for times to come.

In Punjab and Haryana states, trees are successfully planted by the farmers without any subsidy and supply of seedlings since it gives quick returns. In other states, the response is not very encouraging. In Tamil Nadu, *Casuarina equisetifolia* and *Pongamia glabra* are the common species raised by the farmers where arable cropping is not attractive. In Gujarat, *Zizypus mauritiana* and *Moringa pterygosperma* are raised on a large scale. The common practice of raising trees on farmlands consist of either rows of trees on bunds of field boundaries. In Karnataka state, *Pongamia glabra* is raised on bunds as a green manure crop. *Salvadora persica* is raised on bunds for leaf fodder in parts of Rajasthan. In W. Dinajpur, *Dalbergia sissoo* is planted on field bunds. *Eucalyptus hybrid* has been successfully planted in Saharanpur district alone or mixed with Bhabar (Singh and Srivastava 1974). Trees are left within the field in arid and semi-arid areas of Rajasthan as an insurance against drought. The common species are *Prosopis cineraria*, *Zizyphus nummularia*, *Acacia nilotica* ssp. *cupreSiformis* and ssp. *indica*, *Bauhinia purpurea* and *Tecomella undulata*. It has beens hown (Singh *et al.*, 1969) that *Prosopis cineraria* helps to increase crop yields while *Acacia nilotica* ssp. *indica* reduces yield levels. Since monoculture in extensive areas reduce diversity of ecosystems and simplified food chains, it is scientifically desirable to have forest blocks interspersed with cultivation. There are certain inhibitions by the farmers in general, primarily because of small holdings. Another hazard feared by the farmers is about shading effect of trees raised on the farms, their root competition for moisture and nutrients and nesting place for birds which cause damage to crops. The shading effect could be reduced by evolving suitable lopping practices which would also provide leaf fodder for the animals during fodder scarcity (Shah 1976).

Root competition could be minimised by digging trenches along the field (0.5 to 1 m deep). Selection of upright straight boled trees having less crown cover is preferred. *Eucalyptus* sp. and *Acacia nilotica* ssp. *cupresiformis* are the ideal species. Following table gives species of *Eucalyptus* and *Acacias* suitable for various soil-climatic regions of the country.

Soil climatic regions 1	Species recommended 2
Siwalik regions	— *Eucalyptus hybrid*, *E. gomocephala*, *E. citriodora*, *E. camaldulensis*, *Acacia nilotica* ssp. *indica*, *A. calycina*, *A. suma*.
Red sandy soils of S. India	— *E. camaldulensis*, *Acacia auriculiaeformis*, *A. nilotica* ssp. *indica*, *A. suma*.
Lateritic soils of peninsular India	— *E. saligna*, *E. globulus*, *E. sesbania*, *E. resinifera*, *E. eugenoides*, *A. molissima*, *A. decurrens*.
Black soil region of peninsular India	— *E. astringens*, *E. tereticornis*, *E. umbellata*, *Acacia ligulata*, *A. tortilis*, *A. senegal*.
Sandy loam soils of alluvial plains	— *E. serenti*, *E. crebra*, *E. tereticornis*, *A. nilotica* ssp. *indica*, *A. catechu*, *A. senegal*, *A. benthemii*.
Loamy sand and clay loam of semi-arid regions	— *Eucalyptus camaldulensis*, *E. hybrid*, *E. tereticornis*, *Acacia nilotica* ssp. *cupresiformis*.
Temperate regions of N. India	— *Populus nigra*, *P. alba*, *Salix wallichii*, *S. alba*.

There is need to further investigate and conduct performance trials particularly for high hill regions which have not received adequate attention. However, the following information would be useful :

Pines : *P. armandi* (rocky areas of Central Asia)
P. leucoderma (arctic regions of Canada)
P. eldarisa (rocky areas in USSR)

Eucalyptus : *E. gomifera, E. johnstoni, E. urnigera* (tolerates- 15°C)
E. parviflora, E. gunnii, E. niphopila (Snow loving) (8-18°C)
E. aggregata, E. cairympleana, E. dolgalensis (upto -12°C)

Poplars : *P. euphratica* (Sind and along Sutlej doing well in Leh)
P. tremuloides (Alaska to New Foundland)
P. tachamahaca (rocky areas in Canada & Alaska root easily, resistant to cold extreme conditions of wind and drought)
P. candicana (Successful in Leh)
P. suaveolens (Central Asia, one of few species to attain tree size in its location)
P. laurifolia (South Siberian)
P. lasiocarpa (Central and W. China)

Shelterbelts and special techniques

The tree species suitable for planting shelterbelts are different than from establishing roadside avenues, farm forests or for afforestation of wastelands. The chief characteristics of shelterbelt species is either "marked stilling of air in the lower stratum affected" or by "such sharp deflection upward, in the upper half that the depth of leeward stilled mass is substantially increased (Bates, 1920). Trees for roadside avenues are usually shade trees with expensive crown and less subject to browsing by animals while farm forest trees are deep rooted, should not complete with crops for soil moisture and nutrients and should not have extensive cover to provide shade for crop and nesting for birds. The trees and shrubs for waste community lands need be hardy, drought resistant with low water requirements having root system strong enough to penetrate hard layers.

Pattern of shelterbelt planting

According to Gorrie (1944), on sand dunes shelterbelts of 10 rows, more or less are called the "basic" or "multiple use" belts in contradistinction to three row belts which are designated as "intermediate" and single row ones are "buffer strips". "Multiple use" belts on sand dunes provide effective protection to grass cover of about 10-15 times the hight of trees. These belts are planted at right angles to the direction of prevailing winds. The species planted are *Prosopis juliflora, Tamarix articulata, Parkinsonia aculeata, Albizia lebbek, Cordia rothii, Ailanthes excelsa, Dalbergia sissoo, Azadirachta indica* and *Ipomoea carnea. Eucalyptus* is not very successful on sand dunes. Another method which could be tried is pyramidal planting with inner rows of fast growing and high branching trees flanked by slow growing and low branchy species on the outer side. (Bhimaya and Chowdhary, 1960). The technique primarily consists of 13 m wide tree belt planted in pits interspersed with 60 m of grass species at right angles to direction of prevailing winds. In arid zone of Rajasthan, *Albizia lebbek* among all the species, has given survival of 80 percent and a growth in height of 3.4 cm. Survival percentage in other species is *Azadirachta indica* 70 percent, *Prosopis juliflora* 50 percent, and *Tamarix articulata* 50 percent (Bhimaya and Kaul, 1960, Reheja 1964).

It has been shown that crop yield can be increased 150 percent by shelterbelts. Density, size, spacing and species composition of shelterbelt strip depend on the site situations. In the arid zone with a mean wind velocity of 20 km/hour a typical belt may consist of 3-5 rows in some areas and 7 rows in some planted at a distance of 4×4 m. If 9-10 rows of plantations are done, it should be possible to rotate the harvest in such a way that there is always a shelter belt standing. These would provide fuel wood and small timber and may be harvested once in 10 years or so.

Reduction in wind velocity will further deepnd on the degree of penetrability or density and height of trees planted in the shelter belt. A 20 percent reduction in wind velocity is generally taken as the criterion of useful shelterbelt and therefore, the selection of species will depend upon the wind velocity though opinions differ regarding the minimum wind speed reduction which should be considered significant. When shelter belt is dense, wind resumes its normal velocity and pattern at a comparatively short distance from the barrier lead. In case of belt which is partially penetrable, there is a tendency for the streamline flow over the barrier to re-establish its unobstructed pattern gradually and sheltered area is correspondingly wide in extent. Therefore, partially penetrable shelterbelts are more efficient. Optimum degree of penetrability is 30-50 percent.

For Social Forestry, presently the emphasis is on planting species suitable for fuel or for forage. There are a number of species suitable for sericulture (*Morus alba*, *Terminalia tomentosa*, *T. arjuna*, *Quercus incana*), lac rearing insects (*Butea monosperma*, *Zizyphus* species), tannin bearing species, oil yielding plants (*Pongamia glabra*), starch yielding and for other economic uses such as toy industry, cheap furniture, medicinal drugs (e.g. *Elaeocarpus ganitrus* Rudraksh) etc. which need be incorporated under the social forestry programme. However, these species need be properly managed (Srivastva & Pant 1979).

Irrigated farms

If the roads are laid out along fields, the roadside plantation gives a chess board pattern of planting. On either side of the road, three rows could be planted—the avenue or shade row may run along the road margin and the shrub along the outer two rows. *Dalbergia sissoo* may be planted on the avenue row and *Acacia nilotica* ssp. *indica* in the second row and *Zizyphus mauritiana* in the third row. Other species suitable are *Eucalyptus* sp., *Syzygium cumini*, *Casuarina equisetifolia*, *Mangifera indica*, *Grevillea robusta*, *Jacaranda mimosaefolia*, *Azadirachta indica*, *Kigelia pinnata*, *Pongamia glabra*, *Albizia lebbek* and *Delonix regia*. Closer planting on mechanised farms cannot be resorted. This may conform to spacing based on their zone of efficiency on the windward and leeward sides. *Acacia nilotica* ssp. *indica* and *Dalbergia sissoo* are recorded to have given survival percentage of 90 and 70 percent respectively in Rajasthan while *Eucalyptus* has not fully succeeded. 3-3.6 m spacing for planting and 0.3 m spacing for dibbling with subsequent thinning provide a solid stand in the field (Bhimaya and Chowdhary, 1960).

Dry farm areas

In many arid and semi-arid areas, *Prosopis cineraria* regeneration has been recorded throughout the farmed area since the tree is protected and lopped annually. The stand varies from a few trees to about 100 per ha which provide shelter to growing crop. In some areas, *Acacia nilotica* ssp. *cupresiformis* and *Bauhinia purpurea* are protected. *Prosopis juliflora* has been raised in a single row, 2 row and 3 row shelter belt providing protection to fields since it grows faster than *P. cineraria* and is less damaged by wild animals but the plant has to be properly trimmed. One row and sometimes 2 row shelterbelt of *Dalbergia sissoo*, *Albizzia lebbek*, *Azadirachta indica*, *Parkinsonia aculeata*, *Prosopis juliflora*, *Tamarix articulata*, *Acacia nilotica* ssp. *indica*, *Zizyphus mauritiana*, *Tecomella undulata* along the periphery of rangelands would improve germination of grasses. Proper protection of *Prosopis cineraria* and *Zizypus uummularia* in existing rangelands help them to grow fast and provide leaf fodder during lean periods of fodder availability.

It has been recorded that sowings of *P. cineraria* in consolidated loam in furrows has given 70-80 percent survival of seed dibbled in furrows 0.3 m apart, The internal shelterbelt sowings with seed mixture of *Acacia nilotica* ssp. *indica*, *Prosopis cineraria*, *Albizia lebbek*, *Azadirachta indica* and *Tecomella undulata* are used but *Acacia nilotica* ssp. *indica* and *Prosopis cineraria* are relatively drought hardy and give better survival.

Orchards

The orchards require protection from hot dry winds during summer and frost during winters. Thickly planted shelterbelts provide them protection from wild animals and reduce water requirement of plants during summers, The pattern consisting of plant 2 rows of shelterbelts of "intermediate" type, The species prefered are *Prosopis juliflora*, *Albizia lebbek*, *Acacia nilotica* ssp. *indica* as the outer row and *Parkinsonia aculeata*, *Dodonaea viscosa* and *Balanites aegyptica* in the inner row. The hedge row is kept trimmed and the shelter row properly prunned to form thick shelterbelt. *Parkinsonia* is most vigorous and provides 3 rows shelterbelt within 2 Years. Jamoi is closely planted around orchards of Mango in Saharanpur district and exploited regularly for fuel.

Table 10. Plants for farm forestry—Woody species (Fuel, Topfeed and timber of agricultural implements)

Plant Names	Sites for plantation					Remarks
	Farm	Boundary	Field bund terraces	Village roads	Village common	
1	2	3	4	5	6	7
Acacia auriculaeformis	—	+	—	+	—	F
A. catechu	—	+	—	—	+	F
A. decurrens	—	+	—	+	+	F
A. jacquemontii	—	+	+	—	+	F
A. latronum	—	+	—	+	+	F, Fd.
A. leucophloea	+	+	—	+	+	F
A. molissima	—	+	—	+	+	F
A. nilotica ssp. *indica*	+	+	+	+	+	F, Fd. (Also for ravines).
A. nilotica ssp. *cupressiformis*	+	+	+	+	+	F, Fd., T
A. senegal	+	+	—	+	+	F, Fd.
A. tortilis	—	—	—	—	+	F
Acer villosum	—	—	—	+	+	T
Aesculus indica	—	—	—	—	+	Fd, T

Contd.

1	2	3	4	5	6	7
Ailanthes excelsa	—	+	—	+	+	F
Albizzia amara	—	+	+	+	+	F
A. lebbek	—	—	—	+	+	F
Anacardium occidentale	—	+	+	—	—	Fr.
Anogeissus latifolia	—	—	—	+	+	F, T.
A. pendula	—	+	+	—	+	F, T.
Areca catechu	—	+	—	+	+	Fr.
Artocarpus heterophylla	—	—	—	+	+	F, Fr.
Azadirachta indica	—	—	—	+	+	F, Fd., T.
Bauhinia purpurea	+	+	+	+	—	Fd.
B. retusa	+	+	+	—	+	Fd.
B. vahlii	—	+	—	—	—	F.
Bischofia javanica	—	—	—	+	+	F.
Bombax ceiba	—	+	—	+	+	F., Fr.
Borassus flabellifer	+	+	+	+	+	F., T.
Broussonetia papyrifera	—	+	+	—	—	Fb., Fd.
Butea monosperma	+	+	—	+	+	F.
Caesalpinia bonducella	—	+	+	—	—	F.
Calligonum polygonoides	—	+	+	+	+	F., Fd.
Capparis decidua	+	+	+	+	+	F., T., Fr.
Carissa carandas	—	+	+	—	—	F., Fr.
C. spinarum	—	+	+	—	—	F., Fr.
*Cassia siamea**	—	+	—	+	—	F., Fd.
C. auriculata	—	+	+	+	+	F.
Casuarina equisetifolia	+	—	—	—	+	F.
Celtis caucasica	—	—	+	+	+	Fd.
C. eriocarpa	—	—	+	+	+	Fd.
Cocos nucifera	+	+	—	—	—	Fb., Fr.
Dalbergia sissoo	+	+	+	—	+	F.
Delonix elata	—	+	—	+	—	F.

1	2	3	4	5	6	7
Dendrocalamus strictus	—	+	+	—	—	Fd. (Also for ravines)
Emblica officinalis	—	+	+	+	—	F., Fr.
Eucalyptus sp.	—	+	+	+	+	F.
Euonymus pendulus	—	+	—	+	+	F.
Ficus infectoria	—	—	+	+	—	Fr.
F. nemoralis	—	—	+	+	—	Fr.
F. palmata	—	—	+	+	—	Fr.
Gliricidia maculata	—	+	+	—	+	Fd.
Gmelina arborea	—	+	—	+	—	F.
Grevillea robusta	—	+	+	+	—	F.
Grewia asiatica	—	+	—	+	—	Fr.
G. oppositifolia	—	+	+	+	—	Fd.
G. tenax	—	+	+	—	—	F.
Madhuca latifolia	—	—	—	+	+	F., Fr.
Maytenus emarginatus	+	+	+	+	+	F.
Melia azadarech	—	+	+	+	+	F.
Moringa oleifera	+	+	+	+	—	F., Fr.
Morus alba	—	+	—	+	+	F., Fd.
M. indica	—	+	—	+	+	F., Fd.
M. serrata	—	+	+	+	+	Fd.
Olea glandulifera	—	+	+	+	—	T.
Parkinsonia aculeata	—	+	+	+	—	F.
Phoenix sylvestris	—	+	+	+	+	F.
P. dactylifera	—	+	—	—	—	Fr.
Piuus roxburghii	—	+	—	—	+	F.
Pithecolobium dulce	—	+	+	—	—	F.
Pongamia glabra	+	+	+	+	+	F., Fr.
Populus sp.	+	+	+	+	+	F.
Prosopis cineraria	+	+	—	+	+	F., T., Fd.

Contd.

1	2	3	4	5	6	7
P. juliflora	—	+	+	+	+	F.
Prunus sp.	—	+	—	+	—	Fr.
Pyrus sp.	—	+	—	+	—	Fr.
Quercus incana	-	+	+	+	+	Fd.
Q. dilatata	--	+	+	+	+	Fd.
Salix sp.	—	+	+	+	—	F, T.
Salvadora oleoides	+	+	—	+	+	F., Fr., Fd.
S. persica	—	+	+	+	—	Fd.
Syzygium cumini	—	+	—	+	—	T., F., Fr.
S. jambosa	--	+	+	—	—	T.
Tamarindus indica	—	+	—	+	—	T., Fd., Fr.
Tamarix articulata	—	+	—	+	+	T., F.
Tcomella undulata	—	+	—	+	+	T., F.
Toona ciliata	—	+	—	+	—	T., F.
Trema politoria	—	+	—	+	—	F.
Ulmus wallichiana	—	+	—	+	—	F.
Vitex negundo	—	+	+	+	—	F.
Woodfordia fruticosa	—	+	+	+	+	F, T.
Zizypus nummularia	+	+	+	+	+	Fr., Fd.
Z. mauritiana	+	+	+	+	+	F. (Gola, Seb, Mundia and Jogia are superior in Jodhpur)

F. = Fuel
T = Timber
Fr = Fruits
Fd = Fodder
Fb = Fibre

*Kisty, D.V., 1966 recorded good performance on black soil,

Trees such as Buil, Chimu, Tut (Morus) and Ehretia are commonly planted on field bunds and margins in Himachal Pradesh for fuel & fodder.

Alnus nepalensis is extensively planted for fuel in the Himalayan region. The plantation done at a spacing of 2m × 2m. in pits of 60 cm^3. Average production of fuel wood ranges from 4000-6000 cuft for acre, for a rotation of 12 years. One cuft of wood being approximately 15 kg. Cost of planting is about Rs. 700/acre.

Plantation for Sylvi-pastoral management of Community (Gochar) lands

Wastelands near the villages, the Panchayat lands and Village "commons" comprising about 43 million ha in about 5,67,000 villages need plantation and improvement by proper management through mixed forestry so as to provide fodder, fuel and small needs of timber. Survey of some of the areas in Gujarat and Rajasthan (Anonymous1964-1968, Land Transformation Plans) recorded that trees like *Prosopis cineraria, Salvadora oleoides, Anogeissus pendula* and *Acacia senegal* assume a prostrate habit with continued hacking and maltreatment. In the Western Himalayas, *Quercus incana* (Vern. Banj oak) too assumes a similar habit. Since most of these lands are open to grazing and biotic influences the existing vegetation is either stunted or pollarded. Sometimes uneconomic vegetation like *Lantana camara, Berberis*, etc. gains dominance in areas of good rainfall. The area is left to the devastating effects of wind and water and pose erosion hazards thus spoiling the landscape. Similarly mining of limestone, gypsum, tungsten and excavation for brick industry near the villages leave the area prone to wind and water erosion.

In some of the villages, the Gochar lands locally called "Orans", the woody vegetion is conserved and dedicated to a diety though grazing is allowed. Such areas need be managed for development of grasscover for grazing and tree cover for fuel wood, small timber wood required by the village community for agricultural implements and fruits for local community.

While planting community lands for sylvi-pastoral management, selection of species need to be made carefully. The nutritive value of a few common species are recorded in table-10. Since the trees are to be used for fodder one has to be selective so as to provide best leaf fodder for the cattle population which serves not only as fodder during the lean period of fodder availability but also as concentrates. However, suitable lopping practices need be evolved so as to keep the tree species at maximum level of fodder productivity without damaging its other growth parameters. The common lopping practices followed by the villagers are not scientific since all the leaves are lopped except for the terminal bud which is left. Studies by Bhimaya *et al.* (1964) on lopping intensity of *Prosopis cineraria* showed that intensity of lopping does not adversely affect the growth of *Prosopis* trees. Recurrent lopping of trees definitely reduce the leaf fodder yield irrespective of lopping.

Isolation and characterization of the rhizobial strains for some topfeed tree legumes suggested for community lands of Rajasthan such as *Acacia senegal*, *Albizia lebbek* and *Prosopis cineraria* show (Basak and Goyal, 1975) that rhizobia from these legumes were akin to those of Cowpea group in their properties and rhizobial strains of Cowpea group could nodulate these species. Rhizobia from *Acacia senegal* and *Prosopis cineraria* could cross-pollinate while that of *A. tortilis* is more specific.

Legal position for the protection of community lands

Attention to conservation of forests and introduction of planning in their management started in India in the last century in 1865. The first Indian Forest Act (VII of 1865) was passed by Supreme Legislative Council under which Government was authorised to declare forests and wasteland belonging to Govt. as reserved forest. While introducing the bill, Sir Henry Maine gave an assurance to the Council about the desire of the Govt. not to affect or abridge petty rights over the soil or the produce of forest which had been prescriptively acquired by individuals, villagers or wandering tribes. The Act of 1865 was repealed and was replaced by Act XVI of 1927 which holds till to-date. In 1878, while piloting the bill, the assurance given in 1865 about the rights was reaffirmed. This Act provides for the Constitution of Forests and wastelands over which the Govt. possessed proprietory rights into two main classes of forests, reserved and protected forests. This act also contemplated establishment of village forests definitely owned or enjoyed by village communities which after settlement as reserved forests were to be restored to the villagers subject to conditions of management and use, laid down by local Government. This provision exists even today, though it remained inoperative for the most part. It was, however, precursor of the idea of formation of Panchayat Forests. In fact, the rules for Panchayat Forests in Uttar Pradesh have now been conitituted under this provision.

Community lands are protected as Reserve forest under Chapter II or as protected forest under Chapter IV of the Indian Forest Act. Rules for the protection and management of these areas were framed by the Haryana Forest Department by prohibiting grazing, browsing, breaking up of land and removal of forest produce, etc. Private lands are closed under Section-38 of Indian Forest Act and Section-4 & 5 of Land Preservation Act.

Govt. of Uttar Pradesh has framed rules in May, 1972 for Constitution of Forest Panchayats. These rules have recently been revised in 1976, and are applicable to hill districts of Uttar Pradesh. At least one third of the adult residents of a village or villages within which their rights of user have been recognized by a judicial decision or in a forest settlement can resolve to form a Panchayat Forest by adopting the procedure prescribed under rules. They can collect 5-9 persons as members of Forest Panchayat and elect a Sarpanch amongst them who shall be responsible for the proper management of Panchayat forests. The functions of the Forest Panchayats are as under—

i) To prevent damage to trees and for felling only those trees that have been marked silviculturally by Forest Department as fit for exploitation.

ii) To ensure that no encroachment of any kind takes place and no land is broken for cultivation in contravention of the Rules made under Kumaon Nayabad and Wasteland Act 1948 or of any other such Act or of such rules which may be in force.

iii) To erect and maintain boundary pillars.

iv) To carry out the directions and execute the orders given by the Deputy Commissioner to maintain, improve and exploit the forests. Such orders will be issued by the Deputy Commissioner on the advice of the Conservator of Forests or Divisional Forest Officers.

v) To utilize the produce of Panchayat Forests to the best advantage of the village community and of the right holders, recognized by the Commissioner consistent with silvicultural availability.

vi) To close at least 20 per cent of the area for grazing unless otherwise permitted by the authority to be specified by the Commissioner for the purpose; and

vii) To protect the forest from illicit fellings, lopping and other kinds of damage and fire.

Under the new Panchayat Forest Rules 1976, it is "obligatory on the part of the Forest Department to have working plans for all Panchayat Forests prepared in consultation with the Forest Panchayats and keeping in view the requirements of villagers and to bear the entire cost of preparation of all such working plans or projects. The conservator concerned shall get the working plan or projects prepared. The working plan or projects shall be approved by the Chief Conservator of Forests before it is brought into force. Once it is approved by the Chief Conservator of Forests, it shall be the duty of the Forest Panchayat to strictly adhere to the prescription of the working plan or project and not to deviate upon it without the prior approval in writing of the C.C.F.". It is understood that earlier working plans had to be approved by the State Government. Forest Officers preparing the working plans have to take a note of the existing forests as well as the species that can be grown in the specific nature of soil and the terrain requirements of population and of industries, if any, in respect of which information has been given by the concerned authorities to the Forest Department. There is, however, no statutory provision making it compulsory for the working plan officer or the approving authority to hold broad-based discussions with the general, administration technical departments like agriculture, industries, knowledgeable representation of the public living outside the Panchayat Forest and academic and technical persons attached to educational and research institutions.

The plan has to consider basic requirements and this has to be an integrated afforestation plan and not limited to commercial forestry on these forests. An encouraging step taken recently of development of Civil forests is the creation of a post of Divisional Forest Officer (Civil and Soyam Forest) who has to operate on Civil Forests under the control of Revenue Department.

Peoples' involvement in development and management of communiy lands

Revenue Department has taken up a programme of Forestry development in some parts of the Himalaya. The approach to this programme is as below :

1. In forestry development programmes, the 'necessity' of the people rather than the rights are to be considered. They depend for fuel, cattle grazing and other productive consumption activities on the forest resources. Unless their essential requirements are met, they naturally would like to obtain the same by fair or foul means.

2. It has been found that some of the Panchayat Forests are better managed than even the Reserve Forests.

3. The integrated development should be based on 3D approach of pasture development, afforestation and cattle development.

4. Forest Panchayats for such development programmes can constitute nucleus for obtaining institutional finance. They should be involved in the planning and implementation of the programme and management of these forests on scientific lines.

Forest Panchayat funds are frequently utilised for binding up social service Institutions like schools, etc. which is otherwise the state responsibility. Utilisation of funds for improving-plantations are desirable. Forest labour co-operations for utilisation and management ensures better employment opportunities for villagers.

Development of communitylands affected with salinity for Sylvi-pastoral management

In arid and semi-arid conditions, where rainfall is inadequate and frequently the evaporation surpass by far the amount of effective precipitation development of such areas pose special problems. The leaching process is restricted to the top horizons and in consequence the process of salinization is very rapid. The impervious hard subsoil layers of kankar zone of Calcium carbonate nodules is present at varying depths from 30-200 cm. Over-exploitation of the available vegetation, overgrazing and soil compacting by animal hoofing is a common feature. Such areas can be reclaimed for development of pastoral systems by following a series of steps such as enclosure from overgrazing, soil working, reseeding and management on rational basis (Gupta, 1971).

The area is enclosed by proper fencing such as of the ridge mound type, live hedge or angle iron post with barbed wire depending upon the situation and the economic viability. The raised hummocks having better drainage show natural succession of vegetation and main species come up in the area such as *Chloris virgata*, *C. barbata*, *Sporobolus* spp., *Cynodon dactylon*, *Cressa cretica*, *Eragrostis ciliaris* and *Aleuropus lagpoides*, depending upon the situation. A distinct successional trend in the composition of plant species can be seen from bare patches to annual and perennial species. On the border of the natural depressions where water accumulates during the rainy season,plants like *Cressa cretica*, *Portulacca* sp., *Salsola* spp., *Suaeda fruticosa* and *Indigofera paucifolia* can be seen depending upon the degree of salinity or alkalinity in the soil (Gupta, 1973). The area occupied by the vegetation is generally small depending upon the location otherwise most of the area is barren with salt incrustation. For an even distribution of vegetation, a judicious soil working is necessary so that the hard compact surface is broken for speedy leaching of excess of salts by scanty rainfall.

For a suitable soil working, it is necessary to have suitable soil mass of loose soil amenable for rapid proliferation of the root system. Micro-relief of the soil should be capable of being leached of the excess salts and maintaining a salt free condition. Finally, it should be able to retain soil moisture particularly during the period of stress. Therefore contour furrowing of the suitable dimension and at suitable spacing depending upon the slope (60 cm wide and 20 cm deep) should be made with soil mounds opposite the slope. The contour furrows are relatively much effective if placed at 8-10 m apart on areas with 1 per cent slope. These ridges with contour furrows allow leaching of salts maintaining a fairly salt free condition for promoting root proliferation. The ridges also act as an ideal seed bed for the natural vegetation. This results fine progressive succession of natural vegetation in the area and different stages can be seen. During the first year, species like *Chloris virgata*, *C. barbata* show vigorous growth and with improvement in soil conditions are replaced with species like *Sporobolus marginatus*, *S. helvolus*, *Cynodon dactylon*, *Eleusine compressa* and *Dactyloctenum aegyptium*. If the soils are sandy loam to loamy sand, *Cenchrus ciliaris* and *C. setigerus* appear under natural conditions of protection while on silty clay loam to silty loams, *Dichanthium annulatum* can be seen alongwith *Eremopogon foveolatus*. *Dichanthium annulatum* seem to be the final stage of succession in these lands. Where water remains accumulated, *Isleima prostrata* takes over the area.

After 3-4 years of enclosure, many shrubs and undershrubs are observed to have invaded the area some of these in Rajasthan include species like *Tephrosia purpurea*, *Mimosa hamata*, *Lycium barbarum*, *Indigofera paucifolia*, *Suaeda fruticosa* and *Capparis decidua*. Though some of these shrubs are browsed by some animals like goats and camels, these do not constitute a nutritive fodder for the livestock. Therefore, it is necessary to remove some of these species by grubbing during December to January about 30 cm below the soil surface. Repeated operations by digging deeper are required in order of eliminate these species. Though there is possibility to using chemical weed killers, their effect on the soil conditions and animal health need be studied in depth.

Plants poisonous to livestock

List of poisonous plants of U.P. as ascertained by Assistant Disease Investigation Officer (Sheep and Goats), U.P., Pashulok, Rishikesh (Distt. Dehra Dun) is as below.

		Vernacular name
1.	*Quercus floribunda* Lindl.	Moru
2.	*Valeriana wallichii* DC.	Sumaya, Samaljasha
3.	*Erianthus fulvus* Nees	Bichru
4.	*Rubus lasiocarpus* Smith	Hala Hisra
5.	*Coix lachryma-jobi* L.	Marahna
6.	*Strobilanthes wallichii* Nees	Masina, Tilna
7.	*Prunus undulata* Ham.	Aruwa, Aria, Gadharu
8.	*Marsdenia lucida* Edgew	Akruiha
9.	*Prunus officinale wight*	Aundia
10.	*Kalanchoe spathulata* DC.	Biskhapra
11.	*Neyraudia arundinacea* Ham.	Kasarh
12.	*Paeonia emodi* Wall.	Mundara
13.	*Rhododendron arboreum* Sm.	Buras
14.	*Albizzia stipulata* Boiv.	Siris
15.	*Andrachne cordifolia* Muell Arg.	Bhatulia
16.	*Symplocos crataegoides* Ham	Lodh
17.	*Albizzia mollis* Boiv.	Bhandar
18.	*Viburnum stellulatum* Wall.	Risoi
19.	*Rumex nepalensis* Spreng	Khulia
20.	*Corydalis stracheyi* Duthie	Kerua
21.	*Aconitum falconeri* Stapf.	Bish
22,	*Meconopsis robusta* Hk. f. & Th.	Gobaria Bish
23.	*Sencio arnicoides* Wall.	Suraj Kamal
24.	*Rhododendron campanulatum*	Sinru
25.	*Pieris ovalifolia*	Ayar

Table 11. *Percentage constituents on dry weight basis.*

Species	Crude Protein	Crude fibre	Nitrogen free extract	Ash	Phosphorus	Calcium	Magnesium
1	2	3	4	5	6	7	8
Acacia nilotica ssp. *indica* (Babul)	13.9	9.2	69.8	7.1	0.10	2.1	0.4
Acacia senegal Willd. (Kumah)	10.3	9.5	65.7	16.4	0.05	6.9	0.6
Albizia lebbek Benth. (Siris)	29.2	25.3	43.8	7.5	0.20	1.8	0.5
Anogeissus pendula Edgew.	7.6	19.0	65.3	8.1	0.10	3.5	0.3
Anogeissus rotundifolia Blattet Hallb.	8.9	20.0	62.2	8.6	0.10	3.7	0.5
Azadirachta indica(L.) *A.Juss.* (Neem)	12.4	11.4	66.6	9.4	0.10	3.4	0.6
Calligonum polygonoides L. (Phog)	7.4	20.7	64.2	7.6	0.10	2.4	0.8
Cassia auriculata L. (Tarwood)	10.9	12.5	67.3	9.1	0.10	3.7	0.5
Grewia tenax Forsk. (Gangan)	10.3	18.9	61.1	9.5	0.10	3.8	0.8
Gymnosporia spinosa Forsk. (Kankera)	9.3	19.0	63.5	8.1	0.20	1.8	0.8
Prosopis juliflora DC. (Vilayti Khejra)	21.4	20.8	50.0	7.7	0.20	1.5	0.5
Prosopis spicigera L. (Khejra)	13.9	20.3	59.2	6.5	0.20	1.9	0.5
Salvadora oleoides Decne. (Jal)	9.6	9.3	40.2	40.8	0.10	11.9*	0.7
Salvadora persica L. (Khargal)	14.2	9.4	44.9	31.4	0.20	8.8	0.7
Tecomella undulata Seem (Roida)	12.2	15.8	63.0	8.9	0.20	3.4	0.9
Zizyphus nummularia Roxb.	11.7	16.0	65.0	7.2	0.20	1.6	0.3

After Ganguli *et al.*, 1964)

Table 12. *Chemical composition of leaves of plants used as top-feed in Garhwal region on dry matter basis.*

Botanical name	Local name	Crude Protein (%)	Ash	Ether extract	Crude fibre	Calcium	Phosphorus
Quercus incana	Ban	12.13	5.59	5.46	19.43	1.610	0.194
Quercus dilatata	Moru	13.37	6.67	5.21	20.34	1.760	0.6365
Rhododendron arboreum	Burans	6.55	4.47	5.48	26.68	1.270	0.155
Ficus palmata	Kemvo	13.85	17.47	—	11.19	3.850	0.464
Ficus nemoralis	Dudhata	13.93	9.76	2.13	15.50	1.460	0.385
Bauhinia retusa	Guran	15.10	8.03	2.55	20.50	2.090	0.481
Bauhinia vahlii	Mallo	14.26	9.24	2.26	19.71	2.510	0.274
Mallotus philippensis	Kamela	16.24	15.00	—	—	1.373	0.248
Grewia oppositifolia	Bhimal	17.02	13.02	3.82	16.71	3.780	0.483
Celtis caucasica	Kharik	13.33	19.84	2.24	8.25	5.100	0.314
Celtis eriocarpa	Khodaki	12.18	24.20	4.65	15.41	6.000	0.323
		12.24	10.67	3.51	20.42	2.780	0.602
Kenthu, Bhikoi, Achori, Kasmoi, Kujai, Timur *Boehmeria rugulosa*		9.94	20.20		9.00	3.20	0.144

(after Annual reports : Pashulok 1969, 1971-72)·

Table 13. *Contents of CPC, DCP and TDN in leaves of some fodder trees in W. Himalaya* (after Negi, 1977)

Plant species	Vern. name		CPC	DCP	TDN	Palatability
1	2	3	4	5	6	7
Acacia arabica	Thamacheta,	Karimnagar	15.00	—	—	—
	Babul	Hissar	7.04	—	—	—
Acacia catechu	Khair	Ramnagar	13.03	2.90	46.33	Good
Albizzia lebbek	Siris	Izatnagar	16.81	11.59	49.30	Good
Albizzia stiputata	Ohi	Palampur	15.08	4.87	40.23	Toxic
Anogeissus latifolia	Bankli	Ramnagar	7.45	0.57	47.78	Poor
Bambusa arundinacia	Magar	Palampur	18.64	13.50	46.52	Good
Bauhinia variegata	Kachnar	Izatnagar	15.80	9.16	55.54	Good
		Palampur	13.81	4.98	47.92	Good
Cedrela toona	Tun	Palampur	10.71–16.76	—	—	—
Celtis australis	Khirk	Palampur	15.54	9.74	59.42	Good
			11.99	5.13	41.22	Poor
Cordia obliqua	Lasora	Izatnagar	12.81	5.14	26.93	Poor

—Contd.

Programme Implementation

Successful implementation of Tree Planting Programme involves various operational steps such as raising of nurseries, distribution of planting material at the right time at reasonable rates, soil working techniques to be followed depending upon the site conditions, involvement of various people and organisations for planting at the right time and ultimately selection of suitable species according to site conditions and proper management and after care. This would involve training of personnel for programme implementation. However, broad outlines of the various operations are discussed here.

1. *Raising of Nurseries* : Development of nurseries involve several steps such as site selection for nurseries, seed collection and proper nursery practices.

There are appreciable differences in temperatures recorded just on or near the ground and those recorded at some distance from the soil surface. In dry regions, tender seedlings are killed more by lethal temperature than by drought injury. Instead of ground injury, frosts and low temperature near the ground may be responsible for poor survival of young seedlings. Incidence and effect of dew, effect of high atmospheric humidity in coastal areas, effect of intense insolation, effect of hot wind and soil moisture are important. Thus as far as possible the nurseries should have some shade and be near the planting sites. There should be a provision for irrigation near the nursery.

2. *Seeds collection* : Much of the success of plantation programme will depend on good quality seeds of successfully tried healthy species (indigenous or exotic), healthy planting stock from a well-established nursery. The seeds are usually collected from selected group of healthy, middle-aged seed bearers with well-distributed crown. The colour of the seed or fruit is a good indicator of ripeness. Freshy and pulpy fruits loose their hard consistency and become soft when

mature. Collection techniques of seeds vary according to species. Berry may be gathered from the ground but in general, this method should be avoided as fallen seeds may be attacked by insects. Nearly all seeds need thorough cleaning and drying before being stored or sown. Few seeds are dry enough to be stored immediately after collection except those which dry on the tree, such as those of leguminous species. Seeds of most of other species need to be well-aired in a dry atmosphere. Since in freshly gathered seeds of nearly all the species some heating occur when they are piled-up or put into sac and left undisturbed, there is a subsequent loss of viability of at least some of the seeds. The seeds are properly stored with protective chemicals. Germination and plant per cent is determined for samples of various species. Some of the seeds are viable for very short periods such as of *Tecomella undulata*, *Haloxylon salicornicum*, etc. while some seeds have long dormancy period and may not germinate before this is over such as experienced in *Grewia oppositifolia*. However, some seeds having hard seed coat may also require pre-treatment which can soften the seed coat and activate the growth. Sometimes this treatment is achieved in nature such as in *Acacia nilotica* ssp. *indica*. Species with long tap root are generally sown directly while planting stock of 1 or 2 years age is raised in nurseries. Experience has shown that under very dry conditions pre-sowing treatment of seeds should be avoided and it is dangerous to force the seeds to germinate at a definite time which may be unfavourable climatically. Better seed germination is recorded by placing it 1 cm below the soil surface in drills instead of broadcast sowing. Seedlings of some xerophytic species such as *Prosopis juliflora*, *Acacia nilotica* ssp. *indica*, *A. modesta*, *Dodonaea viscosa*, etc. put on much faster growth on the ridged berm of trenches than in the bottom of trenches. Sometimes the seed coat may contain some germination inhibitory substances and it might be desirable to soak the seeds in water overnight so as to wash out the alkaloids, such a situation has been found most common in plants of arid zone.

The seeds should be stored under such conditions that they will keep their viability. Most tree seeds can be stored for a certain time without appreciable loss of viability. Seeds keep best at low moisture content and low temperature generally. Dry cool storage in closed container is recommended for conifer seeds and for most of deciduous species. Moist, cold storage is required for some broad-leaved species such as Oak, Walnut, etc. Seeds of *Quercus incana* are dibbled into the soil just after collection because of low viability. The simplest and oldest method of storage is at ordinary air temperatures in closed containers. These may be protected from moisture by keeping it in tin or plastic containers. It is advisable to test the seeds for genuineness purity and percentage of sound seeds and direct germination in containers similar to those used in nursery or in glass containers according to the size of the seeds. Certain seeds having hard seed coat, viz. *Robinia pseud-acacia*, *Acacia* and *Carob* are prepared for sowing by scarification or by immersion in acid or hot water. Where internal factors prevent germination until physiological changes have occurred cold stratification is required.

3. *Nursery practices* : In dry areas the nurseries are essentially located at places which meet requirements of soil, irrigation and communication. The ideal nursery site should be level, flat and free from stones. Besides permanent nurseries where canal bank and roadside plantations are undertaken temporary nurseries located at short distances are useful. The site should have suitable soil and good abundant water besides availability of labour. Entire nursery should be well-protected by barbed wire or wire netting to predict it from rabbits. Protection against wind is ensured by planting rows of trees or wind breaks around it.

Fast growing species do not need more than eight months in nursery. Sowing should, therefore, be done in late spring. Early sowing would result in too great development at the top, too late sowing may coincide with high temperature resulting in low germination. *Eucalyptus*, if sown too early in cool weather, will germinate slowly or even fail to germinate. All seeds of a species should not be sown at same time but at intervals of about a week in order to avoid losses from sudden downpours. Sowing seeds in a container has several advantages. Containers for sowing should be filled with light soil which has not been used earlier. It should be pressed and levelled carefully in the container. It should be watered when surplus water has drained off. Seeds should be sown and covered with clean sand, the depth of which is equal to diameter of the seeds. Small seeds can be sown and then covered with sand while larger seeds should be pressed lightly into the soil before they are covered.

It is better to sow seeds and then out the unwanted seedlings than to have to replace seed which fails to germinate or seedlings that succeed.

Before and during germination, care should be taken against damage by birds and rodents. Fine wire netting of 10-15 mm mesh should be used to cover containers or seed beds.

The planting stock is raised either in sunken beds of 10 m × 1 m size or directly in containers of polythene, earthen bottomless tubes, galvanised tubes and bricks of sand, clay and FYM in equal proportions (30 cm high, 10 cm and 15 cm sq at the top and bottom respectively). The bricks are embeded in sunken beds and seedlings or stumps raised in them. In humid areas, the nursery beds are raised since waterlogging conditions may sometimes occur. The beds should not be too long so as to allow easy movement of labourers between beds. Generally the beds are 1-2 m wide and 4-6 m long.

Generally the planting stock in the nursery is prepared either by seeds, stump planting or branch cuttings. Soon after the monsoons in arid areas or during the spring where winter rains are there, seeds are prepared for sowing by way of cleaning, pre-treatment, if any and sown in beds in lines about 8 cm apart. Germination usually takes place within a fortnight in many species. Pricking out of seedlings is done either in beds of 10-20 cm or directly in containers mostly of polythene. Sometimes these seedlings are to be protected from hot winds or frost. The seedlings are watered regularly and protected from hot winds by shed and live hedges or from frost by covering. The potted plants sometimes require shifting at intervals so that the root system may not strike the ground. Plant pro-

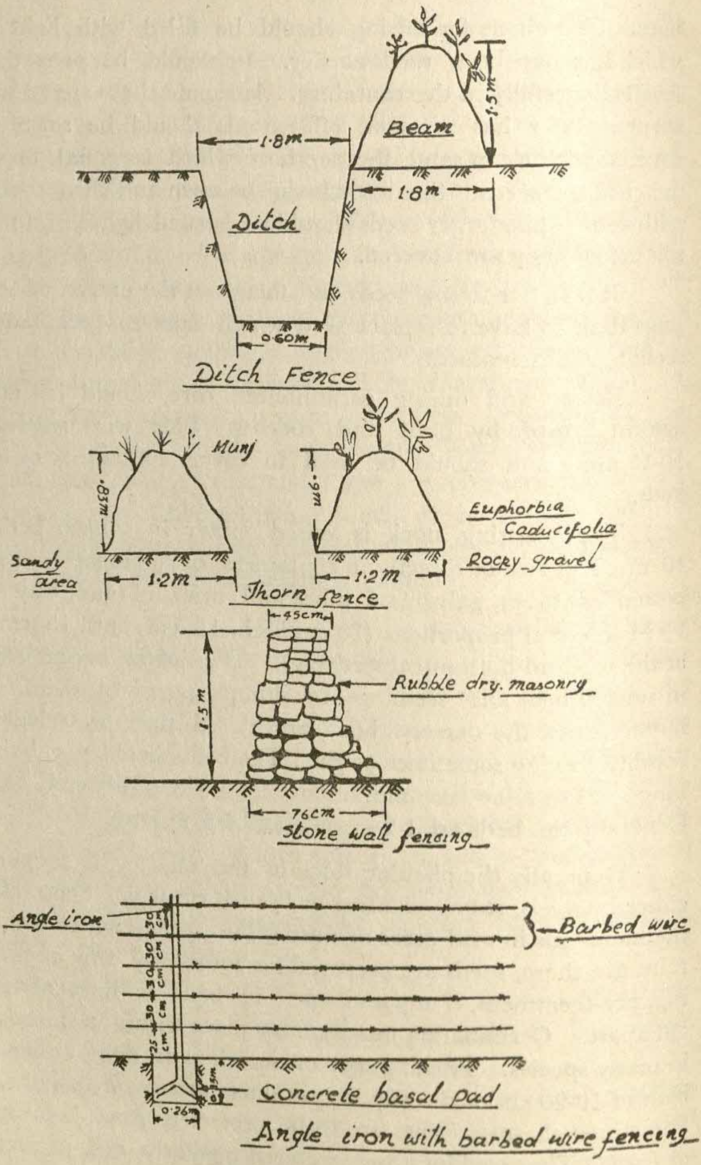


Fig. Types of fencing.

tection measures against termites, beetle, sap suckers, leaf miner and defoliators are taken. One or two year old planting stock is shifted to potting shed.

4. *Plantation* : Site selection is very important for success of this operation though availability of land and objectives of plantation programme are important. A variety of sites are available for plantation and some of the priority areas have been indicated for this programme. Every site, except good land where priority is fixed for raising crops on such lands, poses some hazards such as that erosion on moderately sloping land, excess water where drainage may be needed for its safe disposal or low moisture holding capacity. Generally speaking, land capability classes V to VII are available for plantation programme of afforestation and sylvi-pastoral development while good land upto class IV are available to plantation programme only for farm forestry practices for optimum fuel and fodder production from field margins/bunds, roadside plantation, gardens etc.

5. *Fencing* : The success of the programme for planting and saving trees much depend upon the fact, how effectively these are protected and after-cared. Therefore, fencing of the individual trees or a group of trees forming plantation need be effectively protected. Protection of large-scale plantations and those of individual trees planted on the roadside and in the house need different treatments. The various types of fencings often used are as below :

1. *Ditch fencing*—Usually done on heavy soils by construction of a ditch of trapezoidal shape often 1.8 m wide at the top, 60 cm at the bottom and 1.2 m deep. The excavated soil is heaped as a berm (1·3 m high, 30 cm wide at the top) on the inner side. Seeds of species like *Prosopis juliflora*, *Azadirachta indica*, *Acacia nilotica* ssp. *indica* and stems of *Euphorbia caducifolia* are sown and planted on the berm.

2. *Thorn fencing*—This is done mainly on sandy soils by using thorny bushes and tree species. Some of the species commonly used are *Maytenus emarginata*, *Zizyphus nummularia*, *Prosopis juliflora*, *Euphorbia tirucalli*, etc. Branches of *Anogeissus pendula* are sometimes used for semi-rocky areas, otherwise

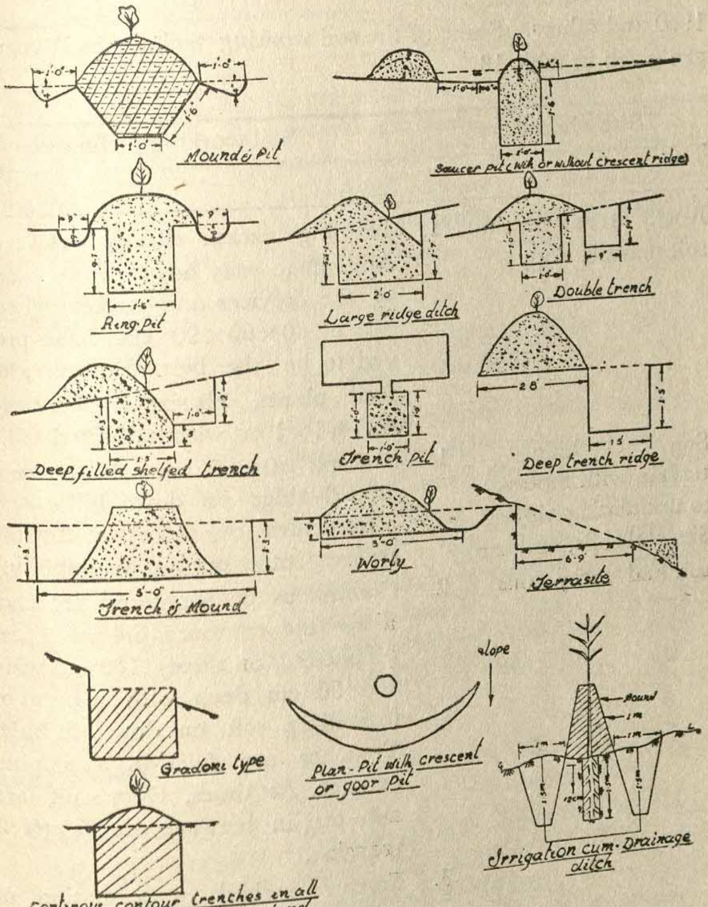
Euphorbia caducifolia, Opuntia dilleni, Cereus haxagonus, serve as an effective live fence, This type of fencing also serves as earthen core wall of 0.9 m height having a base of 1.2 m. Planting of *Erianthus munja* is very common in some semi-arid areas.

3. *Stonewall fencing*—On rocky hill slopes this type of fencing is generally resorted where random rubble is readily available. This is dry masonary fencing about 1.5 m high, 76 cm and 45 cm wide at base and top respectively.

4. *Barbed wire fencing*—Angle iron posts or wooden posts with barbed wire is the general type of fencing recommended on stabilised sandy loam or stony soils. This type of fencing, though relatively expensive, has an advantage since the material can be recycled. Areas subjected to heavy erosion by wind or water need reinforcement of angle irons by cement concrete basal pad. The number of barbed wire strands may vary from 4-5.

Fencing of individual trees is sometimes resorted by any of the above practices or by putting tree girdles prepared with empty asphalt drums, tins, bricks or by special soil working where outer protective live hedge is provided by plants like *Prosopis juliflora, Acacia nilotica* ssp. *indica* or *Euphorbia caducifolia* which can be exploited also.

6) *Soil Working* : Techniques for soil working depend primarily on the site conditions and the objectives of the plantation programme. It primarily concerns water conservation in two ways, viz. by providing moisture for a longer period and by improving root growth. Particularly in the dry zones, soil working trchniques depend primarily for moisture conservation while in the humid zone, safe disposal of surplus water poses another problem since water stagnation in the root zone of young plant may kill it due to insufficient aeration. Soil working techniques will, however, depend upon the soils, slope, depth of watertable and presence or absence of rocks intervening between soil and the permanent watertable. Afforestation techniques for difficult sites have been given by Vyas (1958), Srivastava and Qureshi (1966) Verma 1975 Ghosh, 1977 Seth,



Soil working techniques for different situations (compiled from different sources).

1960 and others. Some of the soil working techniques in vogue are given in table 13.

Site characters	Soil working techniques
1	2
Rocky areas with thin soil mantle, slopy	1. Nothing except effective closure. Advantage may however, be taken of the crevices and pockets where pits of 60×60×90 cm have proved to be the best. However, for fruit plants, pit size is increased to 1×1×1 m with half-filled soil.
Semi-rocky hilly terrain with moderate to undulating slopes. Skeletal soils, murummy soil and rocky soils	1. Soil pit 60×60 cm with crescent shaped ridge on down hill (as recommended by Goor) at flexible espacement as per soil availability.
	2. Continuous or staggered trenches along the contours 6.4 m apart (depending on slope) 160 cm wide and 50 cm deep with a berm of worked-up soil on down hillside. Trenches are filled-in a sloping manner. At times, Goor's pit are also dug in between the staggered trenches.
	3. Furrow method or formation of urulies and planting in the furrows in flat originally sloping land particularly in low rainfall areas.
Undulating to plain terrain clayey loam to stabilised sandy plain.	1. Technique no. 3 may be adopted. For plain areas continuous trenches perpendicular to the general gradient 60 cm wide, 50 cm deep and 6.4 m apart may be followed depending upon the site condition.
	2. Goor's pit (technique 1) at an espacement of 1.8, 3.0 or 3.6 m square.

1	2
Undulating to plain terrain, sandy loam to stabilised sandy plain, pastureland	1. Continuous trenches against the general gradient, 70 cm wide, 50 cm deep and 30.2 m with a berm of worked up soil on downslope side and ploughing the remaining land in between the strips.
Laterite and lateritic soils	1. Saucer pits. 2. Rectangular ridge method in plateau areas of Andhra. 3. Continuous contour trenches in W. Bengal, especially on the sloping lateritic lands. Cross-section of trenches 30×20 cm, generally 30 cm apart. On steeper slopes, every fourth or sometimes every alternate trench is bigger one with a cross-section of 45×45 cm. Sowing/planting is done inside the trench.
Coastal sea bed	1. Leaching out of salts in highly saline areas is the pre-requisite. 2. Planting is done on the ridges, 1 m high. The method in vogue is analogous to Method Steppique being followed in Rann of Kutch, Algeria and Israel. *P. juliflora* is most favoured species.
Littoral swamps, salty marshes and mud flats	1. Pre-requisite is leaching of excessive salts either by removing top silt or construction of broad channels. 2. Planting is done on ridges and mounds. Mangrove species are favoured.

1	2
Sand dunes	1. Levelling of hummocks. 2. Protection against wind and cattle by *Euphorbia tirucalli*, *Prosopis juliflora*, *Clerodendrum*, etc. 3. Providing mulch or obstruction such as erecting wooden plants or branches of shrubs and grasses or mats or sack or any available material at close intervals and perpendicular to the prevailing winds. If wind comes from different directions "Checker board" pattern is used. Maintennace of such obstruction and elimination of cattle or human movement till vegetation develops. 4. Provision of wind breaks or shelterbelts to reduce wind velocity near the ground by exerting a drag on wind and deflecting the wind stream. Continuous trenches or lines of pits perpendicular to prevailing wind direction.
Shelterbelt along agriculture land.	1. Delineation of small farm area with same soil working as for plains. 2. Continuous trenches along periphery of the field, especially perpendicular to the prevailing wind direction.
Shelterbelt along roads	1. Three to five rows of pits and circular trenches on either side of the road as per land availability. Simple pits of 60 cm^3 size a longwith circular trenches 60×60 cm cross-section and 90 cm inner radius of the trench. Pits are

1	2
	staggered or alternated between the rows. 2. If irrigation is possible, fencing of strips 20.1 m wide or more on either side. Simple pits 60 cm^3 along the watering channels at 4 m apart.
Saline and alkali soils	1. Trench and ridge method. 2. Deep pits filled with good soil.
Ravine lands	1. Easing off the gradient of gully heads and diverting surface flow. 2. Contour trenches and ridge method. Ridge slopes should have angle of repose and stabilize them. 3. Rectangular contour trench is recorded successful in ravines. A rectangle 3 m×45 cm is laid out along the contour. Soil is worked upto 15 cm and thoroughly broken-up. Another rectangle of same size is marked out on the uphill side along the first rectangle. The soil of this is dug 30 cm deep. All the clods are broken-up and earth is piled on the top of the first one which is already dug 15 cm deep. The height of the ridge is kept at 30 cm. This provides 45 cm worked-up soil for establishment of plants and the ditch provides moisture. The vertical interval between two rows is kept at 5 m. 4. *Gradoni type trenches* : Trench of 3 m×60 cm×45 cm, 1.5 m×60

1	2
	45 cm and 1 m×45 cm×30 cm at spacing of 3 m×3 m, 3 m×$4\frac{1}{2}$ m, $4\frac{1}{2}$ m×4 m are laid out on the plateau and sloping lands and in gully beds. Trenches are not made exactly on contours. The excavated earth is piled on the down slope and allowed to weather for 1 to 1*a* months. The trenches are then half filled and ridge prepared on down hillside. The seeds are sown in two rows at intervals of 15 cm, one row in the middle of the ridge and the other at the top.**
Water-logged areas (1 m ha)	1. Proper drainage to remove excess of water is the pre-requisite. 2. Ridge and furrow method, open ditch and trenches are planted with highly transpiring plant species, viz. *Eucalyptus robusta*, *Syzygium cumini*, *Salix* sp., *Populus nigra*, *Terminalia arjuna* and *Acacia nilotica* ssp. *indica*. In Uganda (E. Africa), *Cyperus papyrus*+*E. robusta* are planted in wettest parts. This can with standsubmersion for a fortnight. Then *E. saligna* is planted in drained swamps after 8-10 years of first fuel rotation period.
Shelterbelt along	1. Plantation in strips, 40-60 cm wide along the main canal and its bran-

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**Pits of size 60×45×30 cm or 30 cm^3 are dug at spacing 3m×3m or 3m×4 1/2m in between two trenches. The excavated earth after weathering is again put in the pits. Plants and treated cuttings are planted in these pits after 3–4 showers of rains.

1	2
	ches by laying out irrigation channels, 4.5 m apart along the canal. 2. Plantation in blocks along the canal system is based on irrigation unit known as 'Murabba'. The area is divided into 6-8 plots by means of irrigation channels which run along the slopes. On either side of shis channel and on the terminal end of trenches small water channels are laid (Passels) which are connected to main channels by Nakaies. Contour trenches varying in length from 25-40 m are dug perpendicular to Passels and Khalas, these are 4 m apart. 3. Measurement are 45 cm × 30 cm and 30 cm. 4. Khalas width 1 m at top and 50 cm at bottom, 60 cm deep. 5. Passel and trench width 0.42 m at top and 30 cm at bottom and 30 cm deep.
Landslide on the hills	1. Construction of a toe wall. 2. Contour wattlings at 5-7 m interval by digging 1 m deep trench and filling-up with brush wood bundles (5-6 cm diameter). 3. Mulching with thick grass cover. 4. Planting of mulched area with rod of crow bar with 30 cm cuttings of species spaced at 15-20 cm could be vegetatively propagated with the onset of monsoon.

1	2
	5. Providing log, log crib, loose rubble check-dams in drainage channels and plugging small channels with roots of Napier or Hybrid napier.
Shallow heavy black soils	1. Pit planting.
	2. On slopes, staggered pits are preferred (60 × 60 × 60 cm).
Cold desert (Ladakh)	1. Trench-cum-pit type on slopes.
	2. Irrigation-cum-drainage ditch type on ridge. 45 cm high mounds are prepared with excavated soil from ditches around the seedlings planted in 45 cm deep crow bar holes so that salts are leached out from root zone.

Site preparation and soil working is generally done fairly in advance before the planting season. The pits may be circular or ractangular. The dug up material, particularly rocks and boulders, are removed and placed on the down hillside of the pit so as to reduce the runoff. Soil taken out is piled on one side so that presowing showers wet the soil and the pit. In arid areas this may be returned to the pit after digging so as to conserve moisture. Pits may be dug in rows on level ground but staggered on slopes so as to break the force of running rain-water. The distance will depend upon the annual rainfall, slope, soil and the plant species. Generally an espacement of 2.5 m is sufficient. Close spacing need more soil moisture in arid areas than these can support. On rocky sites, plants are placed in suitable soil pockets and in such areas distance between plants may vary considerably.

Contour trenches are dug on slopes and hillsides by first digging the soil and depositing it on down hillside forming a terrace. Interrupted terraces are staggered so as to arrest runoff. Continuous terraces have interrupted undug portion so that scouring within the trench is reduced. Terraces are especially useful when all the tree and shrub vegetation is not likely to recover for a long time. Walls of terraces are of earth and if cutting is done carefully to preserve the live top soil and to deposit it on the steep and the wall of the terraces, vegetation will cover both surfaces quickly. Walls of terraces should have a degree of slope of 1/14 and should be covered with brushwood to protect them from erosion before the vegetation appears.

Crescent shaped trenches as a modification of ordinary contour trenches have been found useful on deep soils where gullies have appeared. These trenches have their two lips pointed uphill and like the straight terraces they are spaced at varying interval and are staggered.

Double crescent-shaped trenches have their horns in opposite direction. The recommended distances between terraces in relation to landslopes (Gorrie, 1946) are recorded in Table 14.

Studies on water harvesting in arid conditions have shown (Evenari, *et al.*, 1971) that within certain limits, the smaller the catchment, the higher the relative water yield per unit of surface area. Therefore, if one could find the optimum size of micro-catchment for each tree or shrub, one could attain a much higher efficiency of runoff utilisation. The method would at the sametime enable the farmer to use large flat areas ordinarily unsuited for runoff farms. Another advantage of micro-catchment over runoff farms is much lower cost of installing and maintaining them.

Table 14. Recommended distances between Terraces in relation to landslope (after Gorrie 1946)

		Horizontal distances			
Slope in ft/100 ft	Equivalant gradient in O	Vertical ft.	distance inch	Av. ft.	Max. ft.
0 34	1/100	2	0	180	230
1 09	1/50	2	6	120	150
1 43	1/33	3	0	100	140
2 17	1/25	4	0	100	110
2 52	1/20	5	0	100	120
3 26	1/17	6	0	1000	110
4 00	1/14	5	3	60	80
4 34	1/12	4	6	45	
5 09	1/11	4	9	45	55
5 43	1/10	4	0	45	55
6 17	1/9	5	0	45	50
6 51	1/8½	5	3	40	50
7 24	1/7½	5	0	60	45
7 58	1/7½	8	0		30
8 32	1/6	6	3	35	40
11 19	1/5	8	0	35	40

Management of Tree Planting Programme

The entire programme of planting for ecological regeneration need to be implemented with peoples participation. This may broadly be classified into 3 phases viz. raising of nurseries and supply of seeds and planting material. This can be undertaken by State farms Corporation, some I.C.A.R., C.S.I.R., D.S.T. Institutes, Central & State Forest Departments and appropriate Rural and Urban Schools and Colleges in the country. Specific responsibility will have to be assigned to each agency for first and second stage multiplication work. ii) Training of personnel : The task training personnel for implementing the plantation work and after care has to be taken by Institutes of ICAR, CSIR, DST, Colleges and Universities and some voluntary organisations like Wild life, Conservation Societies, Environmental protection agencies and similar organisations. They may train experienced trainers, public opinion moulders and decision taking personnel. iii) Initiation of programme by different agencies such as Forest Departments, Universities and ICAR Institutions, National

Demonstration Districts, Integrated rural Development and Small Fermers' Development Schemes of the Goverment of India, operational research and other extension projects of the State and Central Governments and Integrated nutrient supply system villages. The Indian railways, Schools and Colleges can take up a massive programme along the railway tracts. iv) Programme managent and follow up is necessary and the following pattern of organisation and execution has been suggested (Indian Farming, 1977).

Universities/ICAR Institutes/ Forest Departments.	—Supply o material, training of volunteers/farmers in tree planting and care taking.
State Government Department viz. Agriculture, Forest, Soil conservation, social welfare, Tribal and Rural Welfare Deptt.	—At district, block, village level to join, depute staff with requisite know-how.
All-India Yough services	—To provide young enthusiastic personnel as trainees in first instance and trained workers thereafter.
Central Social Welfare board and State level boards, Voluntary Organisations.	—At district/block/village level, depute staff with requisite know-how for training to participate in areas of their operation.
Panchayats.	—Engaging villagers, farmers and other voluntary organisations to undertake this task successfully.
Universities, Schools and Colleges	—To plant trees which can be grown in the area, everywhere in the Campus and to create living museums of useful trees.

All India Radio and other mass-communication media agencies.	—To generate a general awareness of the significance of the programme and to prepare the community for sustained interest and involvement.

The importance of rural institutions has been stressed (Shete 1978) through the decision and policy of democratic decentralisation. There are three basic village institutions viz. village panchayats, co-operative societies and school which play a decisive role in organisation and promoting the Young Conservation Core (YCC). Such a Core should basically be designed to educate young people (10-25 years of age) through useful projects especially in their leisure time. It has two-fold advantages : first distracting youngsters from undersired acts during their leisure and second providing them with educational and working experience through such projects as would bring about desirable changes in their knowledge, skill, understanding, attitude and action. At this age, they are in the most conducive stage to acquire more and more knowledge and skills and hence such educational efforts needed re-enforcement.

Among the three village organisations for constituting Y.C.C., it is suggested that Village Panchayat should encourage the formation of the farmers forum, women' Club and Youth Club at the village level (Shukla, 1963). Barooah (1966) recommended that Panchayat can lend a helping hand for economic projects They can also train the Y.C.C. members. It was also suggested (Singh & Prasad 1967) that Panchayat could help the Y.C.C. by a) appreciating and rewarding youth core members activities; b) guiding and supervising their projects and c) providing financial help to the Youth Club members.

Experiment in Himachal Predesh (1977) involving youth force for plantation programme is interesting where Departments of Education, Forest shall formulate joint programmes. Such programmes shall form a part of the syllabus where students shall be given training on environmental management and preservation. Every School & College shall be provided land for forestry operation. Every class shall work on plantation programme creating blocks which shall be followed by subsequent operations.

Pangtey (1960) suggested that Y.C.C. members should be able to depend on co-operative societies for the supply of seed, fertilizer and other raw materials such as seedlings for the projects. Dubashi (1961), Nanavathy (1962), Barroah (1966), Singh & Prasad (1967) and Prakash (1970) suggests that the co-operatives should offer financial assistance to individual and group projects of the Y.C.C. They may also help the Core member to market their produce.

School teachers could play an important role for organising Y.C.C. They can provide guidance needed for the success of the core activities. The teacher can guide boys, girls in their projects, in holding camps, planning projects etc., for the well-being of the community.

Deshmukh (1960) included theree agencies, viz. i) school teachers, ii) village and iii) youth leader and reported that the three agencies were equally effective in changing the knowledge of the youths in Kitchen gardening project. Gill (1959) observed that the school teacher can work as an advisor to the youth club. In the role of local club leader, teachers can guide the boys and girls in their projects and holding club meetings and parliamentary proceedings. Øommen (1969) in his study of Youth Clubs in rural Delhi found that the Youth Club sought assistance and guidance from several officials in organising and promoting youth club programmes. The most frequently consulted official was the school teacher (32%). Shete (1978) discussed the role of village institutions in organising and providing rural youth clubs. The perceptions of Panchayat Pradhans (PPs) and Youth Club Presidents (YCPs) as to the performance of the Panchayats on the roles, such as providing assistance, giving incentive recognition, giving/arranging training and participation in youth projects, had not been put into practice adequately. Majority of the presidents of both institutions had more or less similar views regarding the role of Co-operative Society. The Co-operative Presidents attach less importance (45%) in training role whereas it is much higher (93%) in case of Youth Club Presidents. As is perceived by the Presidents of both institutions, the Co-operatives did not peiform their role in recognising and promoting the rural Youth Club work to the desired extent. The gap between the role perception and its performance was very wide as compared to the Panchayat. Sometimes, lack of guidance and supervision from extension personnel, lack of incentives, dearth of trained official and non-official leaders, lack of co-operation among village institutions, paucity of finance, time and interest, village politics and factions and absence of dynamic leadership are problems in organising and promoting the rural programmes through Rural Youth Clubs.

The associate village organisations together with economic and educational institutions must be strengthened to give a helping hand in the total rural development works. The Institutions such as Panchayats, Co-operatives and School, even though recognize their role in functioning of Youth Clubs, in actual practice, they themsleves realised to have not contributed much. Therefore, adequate training to members of these institutions as to their role in action rather than the theory is revealed. It would require continuous motivation to them in bringing the rural institutions in close working relationships to Youth Clubs and *vice-versa*.

Suitable grasses and legumes for different regions

Values of soil binding capacity for the grasses have been worked out by a number of workers. Bhimaya *et al.* (1956) found a close and elaborate network of roots comprising their natural spread in all directions in soil to be responsible for the soil binding capacity of roots. He propounded a binding index by adopting a formula $F=W/r^2$ where W is the weight in gms of roots in unit volume of soil and average radius of roots in mm and F the binding factor. Bhaskaran and Chakrabarty (1965) concluded that there existed a close relationship between the binding values calculated in terms of mean root depth and in terms of index calculated by Bhimaya *et al.* (1956). The characteristics namely number, depth, lateral spread, diameter, standard deviation in angular position and percentage roots in soil represent the binding capacity of the grass. Srinivasan, Borde and Tejwani (1962) calculated the values of volume divided by square of the radius of roots of a number of grasses and indicated their degree of ramifications which ranged from 47-1287. The grasses whose values were below 80, were recorded as poor sand binders, while those between 80 and below 200, good soil stabilisers and those above 200, excellent. *Dichanthium annulatum* and *Panicum repens*, were recorded with values 172 and 1287, respectively. Recently, Prajapati *et al.* (1973) based on the merit of root and shoot characteristics in relation to soil protection against erosion worked out an index to represent overall suitability of the grasses for protecting earthen structures at Agra. Out of the 11 grasses for protecting earthen structures, ability of grass was recorded as *Cynodon dactylon*>*Dichanthium annulatum*=*Panicum antidotale*>*P. repens*=*Cenchrus ciliaris*=*Panicam maximum*. *Brachiaria brizantha*=*Chrysopogan fulvus*=*Pennisetum purpureum*> *Cynodon palectostachys* and *Brachiaria mutica*.

Legumes not only help in enriching the soil through nitrogen fixation but provide nutritive forage and food. Preliminary studies on the nodulation of some wild legumes of Rajasthan, have shown maximum number of nodules in *Alysicarpus vaginalis* (Gupta *et al.* 1970) followed by *Crotalaria medicaginea* variety *luxurians.* Effect of fertilizers and defoliatian and debudding on *Crotalaria medicaginea* has also been studied by Saxena Gupta and Dutta (1971).

Arid zone : Most suitable grasses are *Cenchrus ciliaris* (3108), *C. setigerus*, *Dichanthium annulatum*, *Lasiurus sindicus* and *Panicum turgidum.*

Among legumes, *Dolichos lab-lab* var. *lignosis*, *Crotalaria burhia*, *Indigofera cordifolia* and *Rhynchosia minima*, are suitable.

Cenchrus ciliaris and *Dichanthium annulatum* are two versatile grasses which have high adaptability over a wide range of climate and soil and are thus suitable for sandy or sandy-loam soils in areas having rainfall upto 750 mm. Under such situations, legume combinations found suitable are *Alysicarpus rugosus*, *Stizolobium deringianum*, *Indigofera enneaphylla* and *Dolichos lab-lab.*

Black cotton soils : In region with 100 mm rainfall, *Chloris brunei*, *C. gayana*, *Dichanthium annulatum* among grasses and *Aeschynomene indica*, *Desmodium diffusum* Desmanthes virgatus and *Alysicarpus rugosus* among legumes are adaptable.

Red loam and laterite soil : Best species for this region are *Pennisetum clandestinum*, *P. polystachyon*, *P. pedicellatum*, *Panicum, maximum*, *Centrosma pubescens*, *Stylosanthes humilis*, *S. guayanensis* and *Macroptilium atropurpureum.*

Himalayan ranges : Most promising species for hilly areas upto 2000 m are *Arundinella nepalensis*, *Bothriochloa intermedia*, *Eulaliopsis binata*, *Pennisetum clandestinum*, *Phalaris tuberosa*, *Themeda anathera*, *Heteropogon contortus chrysopogon fulvus* and *Cymbopogon* sp. Important legumes would be *Centrosma pubescens*, *Desmodium intortus*, *Pueraria phaseoloides*, *Stylosanthes guayanensis* and *S. hamata.*

Beyond 2000 m constitute home of highly nutritous and palatable grasses such as *Cocksfoot*, *perennial rye*, *Phalaris tuberosa*, *Brome* grass, white and red clovers beside *Lupine* and *Lucerne.*

Grassed waterways : Here the grasses reduce water velocity in the channel. They are good source of forage because of good soil moisture status. Out of the 8 grasses tried on a 1031 m waterway, *Panicum repens* proved the best for stabilisation and forage production, which is followed by *Brachiaria mutica* and *Cynodon dactylon* (Dalal, Patnaik and Singh 1965). Their performance is recorded in Table 15.

Dichanthium annulaum, Cenchrus ciliaris, C. setigerus, Panicum antidotale, Eragrostis superba, Digitaria sp., *Desmodium* sp., *Alysicarpus* species, *Ipomoea carnea, Gliricidia maculata, Sesbania aegyptica* were raised in a waterway on black soils with the object of observing their performance for the stabilization. Due to severe drought mortality was more and establishment difficult. *Dichanthium annulatum* is most suited for the bed of the waterway and *Gliricidia maculata* and *Ipomoea carnea* are good for planting on the margins of the waterway.

At Hazaribagh, *Stylosanthes gracilis* and *Calopogonium orthocarpum* proved quite successful while in Karnataka, *Dichanthium* has been recorded as the most suitable grass. In Tamil Nadu, *Cynodon dactylon, Brachiaria mutica* and *Auxonopus cimicinus*, are recommended.

River and stream banks : Since the sites are characterised by coarse sediments, low nutrient status, loose and unstable planting sites, low moisture availability, flashy flows and abrasive action of moving debris planting material, should be easy to propagate, quick growing and strong with deep and spreading root system. Among the grasses, *Arundo donax, Brachiaria mutica, Cynodon dactylon, Panicum repens* and *Pennisetum purpureum* has been found useful in the regions of Dehra Dun. (Tejwani et al 1975).

Landslides on roadsides : These pose several problems and a number of species have been suggested for the hills depending on the slope and elevation. Some of these are *Eragrostis curvala, Heteropogon contortus, Cynodon dactylon, Eulaliopsis binata, Saccharum munja, Arundo donax* and *Chrysopogon fulvus* for elevations upto 1400 m, for higher elevations plants like *Dactylis glomerata, Lolium perenne* and species of *Agrostis, Festuca* have been used. *Pueraria hirsuta*, provided a good cover on a variety

Table 15 : Performance of grasses in waterway at Dehra Dun.

Species	% Cover (A)	*Ease of establishment*			Forage (kg/ha)	Yield % of *Panicum repens* (C)	Suitability value (A+B+C)	No. of rat holes
		Sprouting (a)	Cover in the Ist yr. (b)	Estab. value (a+b)/2 (B)				
Panicum repens	90	90	94	94	19380	100	284	27
Brachiaria mutica	61	85	100	92	18632	96	249	52
Cynodon plectostachyum	78	98	100	99	13552	70	247	16
C. dactylon	100	98	100	92	6619	34	226	—
Paspalum notatum	70	68	24	46	8267	43	159	7
Urochloa pullulans	27	50	24	37	7106	40	105	10
U. mosambicensis	32	60	18	39	9501	47	118	14
Chloris gayana	34	58	10	34	11524	59	127	18

(after Dalal et al 1965)

of habitats. The plant can be used as forage when cut. It also provides fibre for paper manufacture. (Gupta 1976, 1978 Mathur 1975).

Steep slopes, wastelands and gullies : Various grasses have been tried throughout the country as shown below. Class VI and VII lands at Dehra Dun, have been successfully covered with fuel and fodder plantations. On such lands, cultivation of certain aromatic grasses is being tried out of which *Cymbopogon citratus* and shown good promise. *Chrysopogon fulvus* with *Dalbergia sissoo* proved to be the best. However, *Dichanthium annulatum* failed under the cover of *Dalbergia sissoo*. For ravines of Gujarat, *Dichanthiumannulatum*, *Amphiloptus glabra*, *Andropogon ischaem* are superior binders. *Cenchrus ciliaris* is used for stabilization of peripheral bund and contour bunds.

Saline and Alkali areas : Areas of excessive salt accumulation present difficult problems of soil conservation since high soil salinity (more than 0.5% of total soluble salts), reduce or prevent plant growth, thus providing a focal point for water erosion. Reclamation of salt marshes and other depressional areas, is hastened by encouraging growth of salt tolerant grasses. Such areas provide excellent ground for grazing during the monsoon season. However, measures to encourage drainage of salts, mulching to reduce evaporation and increase infiltration and leaching and sowing of salt tolerant species are recommended. *Sporobolus marginatus*, *S. acroides*, *S. helvolus*, *Cynodon dactylon*, Para grass, Giant Star, Sudan, Marvel are the common grasses used. Low salt-tolerant species include Blue panic, Anjan, Dhaman and Weeping love grass. Promising legumes for inter-row cultivation are *Alysicarpus ruigosus*, *Indigofera linifolia*, *I. cordifolia*, *Cassia tora*, *Desmodium triflorum*, *Phaseolus calcaratus*, *P. trilobus*, *Crotalaria* sp., *Sesbania aegyptiaca*. Salt bush especially--*Chenopods* show good progress.

Earthen bunds or embankments : Prajapati *et al*. (1973) reported 11 grasses (1973). *Cynodon dactylon* with statistically significant supreme root and shoot characteristic afforded excellent protection to terrace bunds against water erosion. This was followed by *Dichanthium annulatum*, *Panicum antidotale*, *P. repens*, *P. maximum*, *Cenchrus ciliaris*, *Brachiaria mutica*, *B. bizantha*, *Chrysopogon fulvus*, *Pennisetum purpureum*, *Cynodon plectostachyum*.

Pennisetum purpureum recorded maximum yield/ha and highest preference in palatability.

Narayana Reddy (1963) recorded unpalatability, easy establishment, easy propagation (vegetative), thick matting on soil and good soil binding capacity due to deep and properly branching root system make it ideally suited for use.

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APPENDIX—I

Climatic parameters of ecological regions of India (Adapted from Legris & Viart 1959)

Station	Height msl (m)	No. of dry days	Dry months	Name of month	*Rainfall*		*Air temp.*		Mean of RH during driest month	Annual mean of saturated defeeit.
					Total during dry month (mm)	Annual (mm)	Mean of driest month	Annual		
1	2	3	4	5	6	7	8	9	10	11
Zone 1—Humid Western Himalaya										
Dras	3067	216	9	7- 3	465	648	18	2	78	3
Jammu	400	105	4	4- 5 10-11	56 26	1069	31, 25	24	40, 57	12
Kargil	2684	259	10	6- 3	172	240	24	9	51	6
Leh	3516	244	9	12- 3 5-10	2246	96	17	6	69,51	4
Ludhiana	247	185	7	3- 6 10-12	113 32	693	34, 25	24	38 50	13
Mukteshwar	2315	26	1	11	11	1360	10	13	50	5
Mussoorie	2310	26	1	11	4	2225	11	14	55	4
Simla	2203	25	1	11	13	1804	11	13	40	5
Skardu	2289	230	10	5- 2	110	160	26	11	69	6
Srinagar	1587	64	3	6,9,11	36 39,11	660	22, 20,8	13	59,64, 68	5

1	2	3	4	5	6	7	8	9	10	11
Zone 2—Humid Bengal—Assam										
Asansol	126	155	6	11-4	110	1430	31	26	48	10
Burdwan	32	140	6	11-4	160	1514	31	26	59	10
Calcutta	6	124	6	11-4	143	1599	30	26	66	7
Darjeeling	2266	23	1	12	7	3211	6	12	69	2
Kalimpong	1202	90	4	11-1 3	36, 28	2189	13, 17	18	75, 61	3
Malda	31	142	6	11-4	97	1438	29	25	58	7
Zone 3—Humid and Himalayan region and Bay Islauds										
Cherrapunji	1314	47	2	12 & 1	31	10797	13	17	70	3
Dibrugarh	106	30	2	11 & 12	49	2792	21	23	83	4
Gauhati	55	69	4	11-2	57	1612	22	24	78	5
Lumding	77	78	4	11-2	126	0302	21	24	92	5
Port Blair	79	66	3	1-3	104	3132	26	26	74	4
Shillong	1501	47	2	13 & 1	30	2149	10	16	78	3
Sitasagar	96	50	3	11-1	76	2491	20	23	87	4
Zone 4—Sub-humid Sutlej-Ganga basin										
Aligarh	187	217	8	10-5	58	784	33	25	41	13
Agra	169	240	9	10-6	142	680	34	25	39	13
Bareilly	173	190	8	10-5	136	1083	32	25	56	10
Bahraich	124	192	8	10-5	148	1159	32	25	55	10
Chaibasa	226	141	6	11-4	125	1309	31	26	59	10
Darbhanga	49	143	6	11-4	65	1265	29	25	62	7
Daltonganj	221	194	8	10-5	167	1085	33	25	51	11

Contd.

1	2	3	4	5	6	7	8	9	10	11
Delhi	217	218	8	10- 5	104	666	33	25	41	12
Dehra Dun	682	149	6	3- 5	85, 67	2161	28, 22	21	38, 64	8
Fatehpur	114	203	8	10- 5	84	885	34	26	53	10
Gaya	111	208	8	10- 5	148	1187	33	26	47	11
Gorakhpur	77	172	7	11- 5	95	1274	32	25	55	9
Gonda	109	198	8	10- 5	134	1322	32	25	55	10
Jhansi	251	219	8	10- 5	16	936	35	27	37	15
Jalpaiguri	82	116	5	11- 3	114	3267	23	24	69	6
Krishnagar	14	136	6	11- 4	164	1457	30	26	62	7
Kanpur	125	209	8	10- 5	101	912	34	25	44	13
Lucknow	113	199	8	10- 5	118	1016	33	25	52	11
Motihari	66	141	6	11- 4	70	1357	28	24	59	7
Mainpuri	157	239	9	10- 6	160	710	34	25	47	12
Midnapur	54	147	6	11- 4	151	1491	31	27	55	9
Patna	52	179	77	11- 5	101	1183	32	26	52	10
Purnea	37	144	6	11- 4	83	1523	28	25	63	7
Ranchi	655	156	6	11- 1 3- 5	46, 107	1476	20, 30	24	54, 37	10
Roorkee	274	159	6	3- 5 10-12	50 44	1049	31, 24	23	35, 60	10
Sabour	37	169	7	11- 5	130	1098	30	25	60	9
Tejpur	78	80	4	11- 2	71	1844	22	24	78	5
Varanasi	76	182	7	11- 5	80	1040	33	26	47	11
Zone 5—Sub-Humid to humid-eastern and South-Eastern upland										
Angul	138	167	7	1-5	177	1289	33	27	53	10

1	2	3	4	5	6	7	8	9	10	11
Balasore	13	132	6	11- 4	182	1574	30	26	67	7
Behrampur	19	138	6	11- 4	150	1732	31	27	69	7
Chandbali	6	126	6	11- 4	150	1732	31	27	69	7
Chanda	193	206	8	10- 5	158	1424	35	27	48	13
Cocanada	7	138	6	12- 5	100	1042	32	28	71	8
Cuttack	26	131	6	11- 4	128	1523	32	27	63	9
Gopalpur	17	131	6	12- 5	131	1156	29	26	76	6
Hazaribagh	611	179	7	11- 5	163	1347	31	24	46	10
Haamkonda	268	179	7	11- 5	124	939	34	27	48	12
Hyderabad	542	178	7	11- 5	123	747	33	26	51	11
Jagdalpur	553	163	7	10- 5	199	1607	31	24	55	9
Kurnool	281	186	7	11- 5	96	629	34	28	45	14
Masulipatam	3	139	6	12- 5	96	1052	32	28	72	8
Nellore	20	142	6	11- 6	186	988	34	29	64	11
Puri	6	111	5	12- 4	67	1362	28	27	75	6
Raichur	399	185	7	11- 5	88	648	33	28	45	14
Rentichintala	106	178	7	11- 5	161	713	35	30	51	14
Sambalpur	148	179	7	11- 5	178	1670	34	27	53	11
Vizagapatam	38	137	6	12- 5	130	962	30	27	72	7
Zone 6—Arid Western Plain										
Abu	1201	221	8	10- 5	71	1564	26	20	38	9
Ahmedabad	49	230	8	10- 5	28	742	34	28	38	15
Ajmer	485	250	9	10- 6	125	527	33	25	37	14
Ambala	272	163	6	10-12 3- 5	46, 59	837	25 32	24	50, 53	12

Contd.

1	2	3	4	5	6	7	8	9	10	11
Barmer	194	268	10	9-6	84	300	34	27	45	14
Bhavnagar	16	233	8	10-5	51	561	33	27	40	14
Brijnagar	321	219	8	10-5	66	925	34	25	39	13
Bikaner	224	276	10	9-6	115	291	35	27	38	17
Deesa	142	258	9	10-6	82	613	33	27	37	15
Dwarka	11	235	10	9-6	112	354	30	26	71	7
Hissar	221	237	9	10-6	122	426	34	25	44	14
Jamnágar	18	191	8	11-5	23	471	31	26	60	9
Jaipur	436	249	9	10-6	127	610	33	25	33	14
Jodhpur	224	262	9	10-6	76	361	34	26	34	16
Kota	257	251	9	10-6	128	750	35	27	35	16
Rajkot	131	232	8	10-5	40	630	32	26	40	14
Sriganganagar	177	280	11	7-5	183	259	34	24	48	14
Surat	11	210	8	10-5	60	1058	31	27	51	11
Zone 7—Semi-arid Lava plateau and Central Highland										
Ahmednagar	657	198	7	11-5	82	601	30	25	34	13
Allahabad	66	182	7	11-5	89	1062	34	26	46	12
Alibag	7	166	7	11-5	72	2078	29	26	70	7
Akola	282	220	8	10-5	119	816	35	27	38	15
Amraoti	369	213	8	10-5	128	851	34	27	46	14
Aurangabad	581	223	8	10-5	118	718	32	26	36	13
Baroda	35	217	8	10-5	78	932	33	26	47	12
Bhopal	501	218	8	10-5	111	1328	33	25	36	13
Bhuj	104	273	10	9-6	111	346	31	26	45	13
Bombay	1	167	7	11-5	39	1808	30	27	69	7
Dohad	333	196	8	10-5	76	717	33	26	60	12

1	2	3	4	5	6	7	8	9	10	11
Gulbarga	458	193	7	11-5	103	746	33	26	39	15
Guna	479	216	8	10-5	105	1253	33	25	39	12
Hoshangabad	302	217	8	10-5	103	1271	34	26	39	14
Indore	556	219	8	10-5	81	882	32	25	39	12
Jabbalpur	393	208	8	10-5	146	1461	33	24	45	11
Kankar	401	181	7	11-5	129	1489	33	25	49	10
Khandwa	318	222	8	10-5	90	780	34	26	36	15
Marmagoa	61	141	6	11-4	76	2559	29	27	68	6
Mahabaleshwar	1382	155	6	12-5	86	6635	24	20	51	6
Malegaon	436	226	8	10-5	101	548	32	26	35	13
Miraj	753	155	6	12-5	110	652	30	25	47	9
Nagpur	311	187	7	11-5	103	1250	35	27	38	14
Neemuch	496	227	8	10-5	56	764	32	25	37	14
Nizamabad	311	214	8	10-5	144	1023	34	27	43	14
Pachmahal	1076	187	7	11-5	102	3022	30	23	43	8
Pendra	622	180	7	11-5	168	1373	31	24	44	10
Poona	559	190	7	10-5	78	673	30	25	46	11
Raipur	295	187	7	11-5	107	1332	35	27	47	12
Ratnagiri	64	171	7	11-5	64	2593	29	27	67	7
Sagar	551	216	8	10-5	107	1210	33	25	38	14
Satna	311	210	8	10-5	140	1153	34	25	44	12
Seoni	618	184	7	11-5	119	1362	32	24	39	12
Sholapur	478	197	7	11-5	93	690	33	27	35	15
Umaria	459	187	7	11-5	117	1373	33	34	42	11
Veraval	8	194	8	10-5	33	504	28	26	58	7

Contd.

1	2	3	4	5	6	7	8	9	10	11
Zont 8—Humid-to semi-arid Western Ghats and Karnataka plateau										
Balahonnur	889	74	4	12-3	56	2616	24	22	80	5
Bangalore	920	122	4	12-3	115	865	28	23	55	8
Balgaum	790	142	6	11-4	177	1293	27	24	51	8
Ballary	449	207	8	12-7	169	50	32	28	45	15
Bidar	710	185	7	11-5	104	857	32	26	43	14
Bijapur	594	191	7	11-5	101	512	3$	26	42	13
Calicut	8	94	4	12-3	57	3085	29	72	72	5
Chitradurg	733	133	5	12-4	112	743	29	25	49	10
Cochin	3	88	4	13-3	135	2929	29	27	71	6
Cocanada	7	138	6	12-5	100	1042	32	28	71	8
Coimbatore	409	193	9	52-4	112	590	29,	26	59,	9
				6-9	152		27		73	
Coonoor	1746	0	0	—	—	1551	—	17	—	4
Cuddalore	12	113	5	2-6	126	1383	32	28	72	8
Cuddapah	130	150	6	12-5	91	768	35	29	53	13
Calingapatam	5	110	6	12-4	65	1025	30	27	76	6
Gadag	650	176	7	11-5	160	620	30	25	49	11
Hassan	960	89	4	12-3	92	889	25	23	73	6
Kodaikanal	2328	0	0	—	—	1688	—	14	—	3
Mangalore	22	22	5	12-4	61	3257	27	27	69	6
Madras	20	135	6	1-6	142	1267	33	28	70	9
Madura	133	144	6	1-4	101	872	30,	28	58	12
				6-7	89		31			
Mercara	1152	96	4	12-3	48	3236	23	20	65	4
Mysore	767	104	4	12-3	33	791	28	24	50	9

Contd.

1	2	3	4	5	6	7	8	9	10	11
Nagapatam	9	133	6	2-7	184	1406	31	28	70	8
Ootacamund	2245	20	1	2	13	1394	13	14	62	3
Pamban	10	180	8	2-9	170	943	29	28	79	6
Salem	278	123	5	12-4	103	977	31	28	57	11
Trivendrum	61	66	3	1-3	151	1696	28	27	73	6
Trichurapali	77	148	6	1-4	92,	871	32,	29	56,	13
				6-7	75		31		51	
Vellore	214	119	5	1-5	134	1073	32	28	60	11

APPENDIX—II

Ecological features of native woody vegetation

Plant species	Habit	Growth	Regeneration	Habitat	Uses	Remarks
1	2	3	4	5	6	7
Capparis decidua	Tree	Slow growing	Coppicing by root suckers	Alluvium and gravels	Wood for fuel and implements	Wood resistant to white ants.
Tamarix articulata	Tree	Fast growing in first few years	Seeding, by cutting, coppices vigorously.	Sandy river bed and low lying land	Protective as shelterbelt, wood for implements	Drought and frost hardy.
Tamarix dioica	Tree	Rapid (12.19 cm m.a.i.) in girth	Abundant regeneration	Sandy river bed and highly saline land.	Fuel	Greater capacity for growing on saline soil.
Tamarix troupii	Small Tree	Rapid (3.45 cm m. a. i.)	Coppicing, by seeds	River banks, sea coast	Fuel, pole, rafters and also protective	Drought and frost resistant.
Grewia tenax	Shrub	Slow	Coppicing, root suckers	Mainly sand stone hills	Fuel	Shoot coppicing of great vigour.

Contd.

1	2	3	4	5	6	7
Commiphora wightii	Tree	Slow	Cuttings	Mainly sandstone hills	Gum-source of Revenue	Drought resistant.
Azadirachta indica	Tree	After first season rapid (0.23-3.05 cm m. a. i.)	Coppicing and root suckers in dry climate and direct sowing	Many habitats	Shade tree, timber and medicinal	Frost tender.
Zizyphus mauritiana	Tree	Rapid (2.44 metre height during 7 yrs.)	Direct sowing, transplanting and root suckers, coppices well.	Dry river beds, sandy gravelly alluvium.	Fuel, timber, thorns for fencing, fruit and leaves as food and fodder.	Frost hardy.
Ailanthus excelsa	Tree	Rapid (0.61 metre height at the end of 2nd season and at 4th season 4.27 metre height and girth 0.76 metre)	Coppicing, root suckers	Planted on road	Shade plant, soft wood and protective	Frost hardy, seedling sensitive to weed.
Prosopis cineraria	Tree	Seedling slow for first few years then rapid	Coppices well to moderate age, root suckers.	All situations except hills	All part used	Young plants sensitive to frost.

1	2	3	4	5	6	7
Acacia nilotica ssp. *indica*	Tree	Seedling slow for first few years then rapid	Direct seeding, coppicing power varies, no root suckers.	Older alluvium and old tank beds.	Fuel, timber, gum and fodder	Young saplings sensitive to frost.
Acacia leucophloea	Tree	Seeding growth fairly rapid (0.61 m at first season)	Coppices well and produce root suckers.	Older alluvium	Fuel, gum and fodder	Tender to frost and light demander.
Acacia senegal	Tree	Slow (7-8 years plants yield gum)	Direct sowing useful also coppices	Hills and hill-side dunes	Timber, gum arabic, fodder and fruits edible.	Frost hardy.
Anogeissus pendula	Tree	Rapid (7 yrs. plant attain 2.13-2.44 m ht. and girth 0.91-1.22 metre)	Coppices and pollards well. Root suckers plentiful.	Hills	Boles, fuel and soil conservation	Frost hardy but suffers from drought.
Salvadora oleoides	Tree	Slow	Coppices well, root suckers re-generate by natural layering	Older alluvium	Wood for building, seed for non-edibele oil.	Only on medium heavy soils, frost hardy.
Salvadora persica	Tree	Slow	Coppices well	Saline soils	Top feed and non-edible oils.	Frost hardy.

Contd.

1	2	3	4	5	6	7
Cordia gharaf	Tree	Slow (1.60 cm) m.a.i.	Coppices well	Tank beds and self sown	Wood for ornamental work	Frost hardy.
Tecomella undulata	Tree	Slow	Coppices well, easily grown seed and by cutting	Deep sandy soils	Wood for building and furniture	Frostand drought resistant.
Calligonum polygonoides	Shrub	Slow (3-4 m in 7 yrs.)	Root suckers	Sandy plains and sand dunes	Fuel	Drought and frost resistant.

APPENDIX—III

Trees and shrubs of economic importance suitable for the hills of Uttar predash, Himachal predesh and Jammu & Cashmir

Name of the species	Local name	Uses	Fodder available during	Method of raising	Time of sowing/ planting
1	2	3	4	5	6
A. *Altitude—upto 1500 m*					
Acacia catechu	Khair	Leaves and twigs for fodder, wood for agricultural implements.	June-August	Sowing (Suitable for shallow soils)	June-July
Aegle marmelos	Bael	Leaves and twigs for fodder	-do-	Sowing and seedlings	June-July
Albizia lebbek	Siris	Leaves and twigs for fodder, wood for agricultural implements.	June-Sept.	Sowing, Seedlings and stumps	-do-
A. stipulata	Siran	-do-	-do-	Sowing & Seedlings	-do-
A. julibrissin	Kurmra	Leaves and twigs for fodder	May-July	-do-	-do-
Anogeissus latifolia	Dhaura	-do-	July-Oct.	Seedlings	-do-
Bauhinia variegata	Kachnar	Leaves and twigs for fodder, leaves for sericulture	-do-	Sowing & seedling	-do-

Contd.

1	2	3	4	5	6
B. purpurea	Khairwal Guiral	Leaves and twigs for fodder	Oct.-March	-do-	-do-
Boehmeria macrophylla	Sinsaroo	-do-	Jan.-May	-do-	-do-
Bombax ceiba	Semul	Leaves and twigs for fodder, soft wood	June-July	Sowing, seedling and stumps	-do-
Bridelia retusa	Ekdama	Leaves and twigs for fodder	June-Sept.	Sowing, seedlings	-do-
B. verucosa	Gondhi	-do-	July-Sept.	-do-	-do-
Cassia fistula	Amaltas	Leaves and twigs for fodder, ornamental, avenue planting.	July-Sept.	Sowing, seedlings	June-July
Cedrela toona	Toon	Leaves and twigs for fodder.	-do-	Seedlings	July-Aug.
Cordia obliqua	Lissora	-do-	June-Sept.	-do-	-do-
C. vestita	Baisola	-do-	March-July	-do-	-do-
Dalbergia sissoo	Shisham	Leaves and twigs for fodder, wood for agricultural implements and fuel.	July-Dec.	Sowing, seedlings and stumps	June-Aug.
Ehretia laevis	Khoda	Wood for fuel.	—	Seedlings	July-Aug.
Emblica officinalis	Amla	Wood for fuel, fruits	—	-do-	-do-
Ficus cunia	Khain, Khinna	Leaves and twigs for fodder, fibre from bark.	Oct.-Feb.	-do-	-do-
F. gibbosa	Chanchri	Leaves and twigs for fodder.	July-Dec.	-do-	-do-

1	2	3	4	5	6
F. glomerata	Gular	-do-	-do-	-do-	-do-
F. hispida	Goblia	Leaves and twigs for fodder, fibre from bark.	-do-	-do-	-do-
F. palmata	Pheru	Leaves and twigs for fodder.	-do-	-do-	-do-
Flacourtia indica	Kango	-do-	Sept.-Dec.	-do-	-do-
Garuga pinnata	Kharpat	Leaves and twigs for fodder, wood for fuel.	July-Sept.	-do-	-do-
Grewia disperma	Kath Bhimal	Leaves and twigs for fodder.	-do-	-do-	-do-
G. elastica	Dhaman	Leaves and twigs for fodder, fibre from bark.	-do-	-do-	-do-
G. oppositifolia	Bhimal	-do-	Aug.-Feb.	-do-	-do-
G. sapida	Phalsa	Leaves and twigs for fodder, fruit.	July-Sept.	Sowing and seedlings	June-May
Grevillea robusta	Silver Oak	Wood for fuel, ornamental.	-do-	Seedlings	July-Aug.
Holoptelea integrifolia	Kali-papri	Leaves and twigs for fodder.	July-Dec.	-do-	-do-
Heteropanax fragrans	Tarla	Leaves and twigs for fodder, leaves for sericulture.	July-Sept.	-do-	-do-
Laucaena leucocephala		Wood for fuel and leaves and twigs for fodder.	-do-	-do-	-do-
Litsaea polyantha	Karka	Leaves and twigs for fodder.	-do-	-do-	-do-
Mallotus philippinensis	Ruina	Fuel and dye	Jan.-Dec.	-do-	-do-

Contd

1	2	3	4	5	6
Marlea begonaefolia	Kimu	Fuel and leaves and twigs for fodder.	July-Sept.	-do-	-do-
Melia azedarach	Dainkan	-do-	July-Oct.	Sowing and seedling	June-Aug.
Mellettia auriculata	Gauf	Leaves and twigs for fodder.	July-Sept.	Seedlings	July-Aug.
Mitragyna parviflora	Phaldu	-do-	-do-	-do-	-do-
Morus alba	Shahtoot	Leaves for sericulture, leaves & twigs for fodder, basket and wood for fuel.	July-Dec.	Stumps and seedlings	-do-
Ougeinia oojeinensis	Sandan	Leaves and twigs for fodder, wood for agricultural implements & fuel.	-do-	Seedlings	-do-
Pterospermum acerifolium	Kanak-champa	Leaves and twigs for fodder.	July-Sept.	Sowing and Seedling.	June-Aug.
Putranjiva roxburghii	Putjiyava	Leaves and twigs for fodder and wood for fuel.	-do-	Seedlings	July-Aug.
Sesbania aegyptica	Jaent	Leaves and twigs for fodder.	July-Sept.	Sowing and seedlings	June-Aug.
Sterculia pallens	Khadrala	-do-	Nov.-March	Seedlings	July-Aug.
S. villosa	Udalla	-do-	May-July	-do-	-do-
Syzygium cumini	Jamun	Leaves and twigs for fodder & fruit.	Nov.-Feb.	-do-	-do-

1	2	3	4	5	6
Terminalia bellirica	Baheda	-do-	May-Sept.	-do-	-do-
T. tomentosa	Asna, Sain	Leaves and twigs for fodder, timber.	Nov.-April	-do-	-do-
Trema orientalis	Khagshi	Fodder (Leaves and twigs for fodder), bast fibre.	July-Dec.	-do-	-do-
T. politoria	Kuri	-do-	Nov.-March	-do-	-do-
Woodfordia fruticosa	Dhaula	Leaves and twigs for fodder.	Oct.-Feb.	-do-	-do-
Zizyphus xylopyra	Kath-Ber	-do-	July-Nov.	Sowing and seedlings	June-Aug.
		B. Altitude—1500-3000 m			
Acer villosum	Kainju	Leaves and twtgs for fodder. wood for fuel.	April-June	Seedlings	July-Aug.
Albizzia odoratissima	Kali-Siris	Leaves and twigs for fodder, wood for agricultural implements.	March-May	Sowing and seedlings	June-Aug.
Bauhinia retusa	Semla	Leaves and twigs for fodder, gum wood for fuel.	Nov.-March	-do-	-do-
B. vahlii	Malu	Leaves and twigs for fodder,	Feb.-March	Sowing and Seedlings	-do-
Boehmeria rugulosa	Genthi	Leaves and twigs for fodder, wood for turnery.	Sept.-March	Seedlings	July-Aug.

Contd.

1	2	3	4	5	6
B. platyphylla	Khaksha	Leaves and twigs for fodder.	Sept.-Oct.	Seedlings	July-Aug.
Cedrela serrata	Darlu	-do-	April-Dec.	-do-	-do-
Celtis caucasica	Kharik	-do-	March-June	-do-	-do-
Cornus macrophylla	Khaksha	-do-	March-July	-do-	-do-
Euonymus hamiltoniaus	Dadul	-do-	-do-	-do-	-do-
E. lacerus	Lichhoi	-do-	-do-	-do-	-do-
Ficus roxburghii	Timla	-do-	Jan.-Dec.	-do-	-do-
F. scandens	Chachri	-do-	Oct.-March	-do-	-do-
Grewia oppositifolia	Bhimal	Leaves and twigs for fodder, fibre from bark.	Aug.-Feb.	-do-	-do-
Juglans regia	Akhrot	Leaves and twigs for fodder, wood for turnery.	May-Nov.	-do-	-do-
Leucomeris spectabilis	Phusara	Leaves and twigs for fodder.	July-Feb.	-do-	-do-
Ligustrum compactum	Kakurchha	Wood for turnery, leaves and twigs for fodder.	March-July	-do-	-do-
Morus serrata	Kimu	Leaves and twigs for fodder, wood for agricultural implements.	June-Nov.	Seedlings and Stumps.	-do-
Olea cuspidata	Kahu	Leaves and twigs for fodder, wood for turnery	March-Sept.	Seedlings	-do-
O. glandulifera	Gair	Wood for agricultural implements, leaves and twigs for fodder.	March-April	-do-	-do-

1	2	3	4	5	6
Populus ciliata	Pahari Pipal	Wood for turnery, leaves and twigs for fodder.	March-Sept.	Seedlings and Stumps	-do-
Pyrus pashia	Mohal	Leaves and twigs for fodder.	March-Oct.	Seedlings	July-Aug.
Quercus incana	Ban	Wood for fuel and agricultural implements; leaves and twigs for fodder.	March-April	Seed, Seedlings	June-Aug.
Q. dilatata	Moru	Leaves and twigs for fodder, wood for agricultural implements.	April-May	Sowing/ planting	-do-
Robinia pseudo-acacia		Wood for fuel, leaves and twigs for fodder.	July-Dec.	Seedlings	July-Aug.
Salix daphnoides	Bashroi	Fibre from bark, leaves and twigs for fodder.	-do-	Seedlings, stem cuttings	-do-
Saurauja nepalensis	Gogina	Leaves and twigs for fodder.	Oct.-March	heedlings	-do-
Spermadictyon suaveolens	Padera	-do-	July-Sept.	-do-	-do-
Ulmus wallichiana	Mai	Wood for fuel, leaves and twigs for fodder.	May-Oct.	-do-	-do-

APPENDIX—IV

Popular names habit and propagation method

Scientific name	Popular name	Habit	Propagation method
1	2	3	4
	A. Trees with Ornamental foliage		
Acacia auriculaeformis A. Cunn ex Benth.	Australian Wattle	Handsome evergreen tree with pendulous branches and leaf-like phyllode.	Seeds
Anogeissus pendula Edgew.		Medium-sized tree with drooping branches. Leaves small.	Seeds
Azadirachta indica A. Juss.		Hardy tree	Seeds, viability low.
Emblica officinalis Gaertn.		Handsome medium-sized tree with beautiful feathery leaves and mottled stem.	Seeds, grafted
Eucalyptus citriodora Hooker	Blue gum tree, native of Australia	Tall tree with slender trunk, clean, few branches. Leaves lemon scented.	Seeds. Grows rapidly.
Eucalyptus filicifolius F. Muell.		Ornamental *Eucalyptus* with profusion of crimson flower.	Seeds.
Filicium decipiens Thw.	Fern tree	Evergreen tree of medium-size having fern like leaves. Crown compact and globular.	Propagation by seeds.

1	2	3	4
Sapium sebiferum Roxb.	Chinas tall tree	Medium-sized deciduous tree, leaves resembling those of Shisham.	Seeds. Frost resistant.
Tamarindus indica L.		Big evergreen tree with spreading crown.	Seeds.
		B. *Shade Trees*	
Diospyro embryopteris Pers.	Introduced from China	Evergreen tree with spreading habit. Leaves smooth.	Seeds.
Eugenia cuspidata Berg.		Medium-sized evergreen tree, crown shady of bright green leaves and stem light yellow	Grows from seed.
Eugenia jambolana Lam.		Large tree with dark stem	Grown from seed.
Ficus infectoria Roxb.		Large shady tree 12-14 m with aerial roots.	From seed. Branch cutting produce tree with low-spreading crown and ugly stem.
Ficus retusa L.		Shady tree, spreading, with dark green leaves, 12-13 m	Cuttings.
		C. *Foliage trees*	
Agathis australis Salisb.	New Zealand Kauri	Erect tall tree	Usually by vegetative methods.
Ailanthus excelsa Roxb.	Tree of heaven	Large quick-growing deciduous tree	Can grow easily by seed.
Alstonia scholaris Br.	Devil's tree	Evergeeen tall tree	Propagated usually by layering or root cuttings.

Contd.

1	2	3	4
Araucaria cooki R. Br.	Hoop pine	Tall evergreen often with spreading branches and quick-growing.	Propagated vegetatively by layering. Also by seed. Good for planting in tubes, on lawns or to form avenues.
Araucaria cunninghamii Sw.	-do-	—	-do-
Araucaria excelsa Br.	Norfolk Island pine	—	-do-
Araucaria bidwillii Rk.	Monkey puzzle tree.	—	-do-
Casuarina equisetifolia Forst.	She-Oak wood	Leafy, quick-growing tree, Xerophytic in habit.	Usually propagated by seed.
Cupressus funebris Lindl.	The weeping or mourning Cypress	Evergreen tall, erect tree up-right and conical in form.	Propagation by seed or by vegetative methods. A common tree of Moghul gardens.
Grevillea robusta A. Cam.	The Silver Oak	Tall evergreen tree of fast growth	Easily raised from seed
Melia azedarach L·	—	Large tree of rapid growth, deciduous in habit.	Easily propagated by seed
Polyalthia longifolia Thw.	The Mast tree	Moderate-sized, evergreen, symmetrical up-right tree.	Easily propagated by planting fresh seed.
Putranjiva roxburghii Wall.	Jalpatri (Hindi)	A medium-sized evergreen tree with a very neat spreading habit.	Propagation by seed.

1	2	3	4
Ravenala madagascariensis	The travellers tree of Madagascar.	Tall tree, evergreen in nature.	Propagated from seed or by suckers produced under mature trees.
		D. *Flowering Trees*	
Acacia dealbata Link.	Silver wattle, native of Australia.	Small tree, evergreen in nature.	By seeds, more usually from suckers. Can be grown as wind breaker.
Amherstia nobilis Wall.	Queen of flowering trees, native of Burma	Medium-sized evergreen tree with slender branches.	Propagation by layering or gooti. Good for avenues as a single on lawn.
Bauhinia acuminata L.		Small tree, always in blossom.	Propagation by seeds.
Bauhinia alba Buch.-Ham.		Dwarf, round-headed tree.	Propagation by seeds.
Bauhinia corymbosa Roxb.		Scandent shrub with small leaves.	—do—
Bauhinia purpurea L.	Mountain Ebony Purple *Bauhinia*	Good medium-sized tree about 8m to 10m tall, evergreen in nature.	Very easily propagated from seed. Needs little protection till fairly well grown.
Bauhinia tomentosa L.		Evergreen shrubby tree.	Seed
Bauhinia triandra Roxb.	Pink *Bauhinia*	Shrubby tree.	Seed

Contd.

1	2	3	4
Bauhinia variegata L.	Variegated *Bauhinia*	Medium-sized deciduous tree with young shoots brown pubescent.	Usually propagated by seed.
Bignonia crispa Buch.-Ham.	Padiri	Handsome tree with drooping boughs, funnel-shaped delicately fragrant flowers.	By layering
Bombax ceiba L.	The Silk cotton tree	Tall deciduous prickly tree with soft wood.	Easily propagated from seed. Makes very beautiful subject for lawn.
Boulsanthus speciosus Harms.	Rhodesian Wistaria, native of Rhodesiaand S. Africa.	Slow-growing tree with dark green pinnate leaves. Droop flowers like Wistaria racemes.	By seed.
Brassaia actinophylla	Native of Queensland.	Small tree with large radialy divided leaves.	—do—
Brownea ariza Banith	W. India Mountain rose	Small spreading tree with beautiful foliage; leaves droop in heat.	—do—
Brownea coccinia Loefl. ex Griseb.	W. India Mount Rose.	Small tree 2-3 m with handsome compact growth with dazzling heads of scarlet flowers. No mass flowering.	By layers. Susceptible to hot summer winds.

1	2	3	4
Brownea grandiceps Jacq.	The rose of Venezuela. Native of Venezuela.	Probably the best of the Browneas. Medium-evergreen tree with gracefully drooping branches.	Propagation by seed. Takes 10-12 years to blossom. Good for growing on lawns. Needs care when young.
Butea monosperma (Lamk.) Taub.	Bastard Teak or Bengal Kino tree.	Moderate deciduous tree, unattractive.	Easily propagated by seed. Planted on boundaries of gardens.
Callistemon lanceolatus DC.	The bottle Brush teee. Native of Australia.	Small erect growing evergreen species.	Propagated from seed or by cuttings. The first method is very slow. Shoots prunned after flowering. Waterings done freely in summer. Suitable for lawns.
Camellia japonica Wall.	Camellia. Native of Japan.	Small slow-growing erect bushy tree; evergreen species.	By seed or by layers or cuttings. Makes excellent plant for shade on northern aspects of buildings. Needs shelter from wind.
Cassia fistula Linn.	The Indian Laburnum	Medium-sized deciduous tree, common in Indian forests.	Propagation from seeds or from root suckers. Young plants delicate and do not stand transplanting well. Good for lawn or avenues.

Contd.

1	2	3	4
Cassia grandis Linn.	Horse *Cassia* or Pink shower.	Spreeding, elegant, quick growing tree, deciduous in nature.	Propagated from seed or from root suckers. This one also is a delicate species. Good for Lawns
Cassia javanica Linn.	The Java *Cassia*. Native of Malaya Islands.	Fast-growing deciduous species, medium-sized or tall.	From seed or from root suekers. Needs to be looked-after when young. Good for planting on lawns or even avenues.
Cassia marginata Roxb.		Medium-sized deciduous tree with spreading and drooping branches.	By seed or by root suckers. Very beautiful species, good for Lawns.
Cassia nodosa Buch. ex Ham.	The Pink Mohur. Native of Burma & Malaya	Tree with spreading crown; flower in clusters appearing like rose bunch on long branches when leafless.	Need to be saved from hot winds.
Cassia renigera Wall.	Burmese Pink *Cassia*	Medium-sized tree, 18 to 20 ft.	By seed.
Choriosa speciosa St. Hill	Mexican Silk cotton tree	Beautiful tree with bottle-shaped green trunk.	Fast growing tree, raised from seed.
Cochlospermum gossypium DC.	Yellow Silk cotton tree	Medium-sized deciduous tree.	Propagated from seed easily. For planting at the ends of gardens to farm background.

1	2	3	4
Cordia sebestena L.	Scarlet *Cordia*	Small tree with compact growth, wrinkled leaves, flower at the end of the branches. Native of Cuba and tropical America.	Seed or layers.
Colvillea racemosa Bojer	Colville's Glory. Native of Madagascar	Leaves pinnate, habit umbrella-shaped as in Delonix. Flower in large drooping clusters.	Seed propagated.
Couropita guianensis Abl.	The cannon ball tree. Native of Tropical America.	A tall-growing deciduous tree. Fruits size of small coconuts.	Propagated easily from seed or from suckers. Good for lawns.
Crataeva religiosa Forst. f.	Caper tree	Small tree with crooked branches. Flowers in leafless condition.	Frost tender, slow-growing, suitable for planting in triangular plots in towns.
Delonix regia Raf.	Gul Mohar. Native of Madagas.	Spreading umbrella like tree.	From seeds, also from cuttings.
Delonix elata (L.) Gamble	White Gul Mohar introduced from Abyssinia by Arabs.	Short and stumpy tree with umbrella like crown.	—do—

Contd.

1	2	3	4
Dillenia indica L.	Chalta tree.	Erect evergreen tree with rounded crown. Leaves broad pointed. Flowers borne at the end of branches.	Propagation by seed. Frost Susceptable tender.
Samanea Saman (Jacq.) Merr.	The Rain tree; Native of America.	Large, handsome, spreading, evergreen tree. Quick-growing and of value as fuel.	By Seed
Erythrina blakei Hort.		Small tree, shrubby.	By cutting/seeds
Erythrina crisca-galli L.	Cockspur, Coral; Native of Brazil.	Dwarf tree.	—do—
Erythrina indica Lam.	The coral tree	Tall deciduous quick-growing tree armed with black prickles.	Easily propagated by seed and cutting which grow readily.
Ficus beghalensis L.	Banyan tree	Often epiphytic leave large feathery. Tree gives excellent shade.	By cutting/transplant.
Gliricidia maculata HBK	Spotted *Gliricidia* or Madre tree. Native of Trop. America.	Small quick-growing with feathery leaves. Flowers resemble those of Wistaria.	From seed or cuttings 2.5-3mm, wood brittle.

1	2	3	4
Guaiacum officinale L.	Lignum Vitae Tree or Tree of Life. Introduced from W. Indies.	Shrubby tree with small dark green leaves. Flower in clusters.	Raised from seed.
Hibiscus collinus Roxb.		Small tree with spreading branches and shaped leaves.	cutting/transplant
Jacaranda mimosaefolia D. Don	A native of tropical America	Medium quick growing deciduous tree.	Propagated by seed or layers. Good for lawn. Also for avenues.
Kigelia pinnata DC.	Sausage tree, Native of Australia	A spreading rather coarse, evergreen species grown for shade.	Easily propagated from seed. Good for avenue purposes.
Kydia calycina Roxb.	Roxburgh's Kydia	Small tree with large leaves	From seed. 5-7 cm seedlings transplanted, quick growing.
Lagerstroemia flos-reginae Retz.	Queen's flower or Pride of India.	Small-sized evergreen tree with light grey smooth bark. In moist districts it is a large tree. Flowers in terminal panicles 30-60 Cm high.	From seed, transplanted when one year old. Flower 3-5 years after planting. Heavy prunning of side branches necessary.
Lagerstroemia thorelli Gagnep.	Queen's flower or pride of India.	Dwarf bushy tree	Easily growing from seed.

Contd.

1	2	3	4
Lysidice rhodostegia Hance	Rose of China, Native of S. China.	Large handsome tree with pinnate leaves bearing erect loose panicles of flowers.	Seeds
Madhuca indica J.F. Gamel	The Mohwa Tree, Indian tree	Medium-sized tree, deciduous. Blossoms at night.	—do—
Magnolia campbelli Hk. f. & Th.	—	Small evergreen tree of Himalayas.	All the species of Magnolia need to be popularised.
Magnolia grandiflora Linn.	—	A small evergreen tree. 10-12 ft hight. Very slow growing.	Propagated by layers of gootying or planting fresh seed which need protection from red ants. Needs shady situation.
Mesua ferrea L.	The iron wood tree	Moderate-sized evergreen tree of slow growth with straight stem.	Propagated from seed sown fresh. The plant does not bear transplanting well.
Michelia champaka Linn.	—	A medium-sized evergreen tree	By layers or seed. A tree which can be grown in house gardens for flowers.
Millingtonia hortensis L.	The Indian Cork tree.	Tall straight, rapid growing evergreen species with brittle bark.	Propagated easily from seed and suckers. Good tree for avenues.
Moringa oleifera Lamk.	Drumstick tree or Horse radish	Pretty small tree with divided leaves.	Seed/cuttings

1	2	3	4
Milletia ovalifolia Kurz.	Moulmein Rosewood	Small tree, flower in leafless condition covering the tree.	Seeds
Mussaenda glabrata (Hk f) Hutch.	Paperchase tree or Dhotri tree	Small tree with tendency to climb stems and veins	Seeds
Ochna squarrosa L.		Small tree	Raised from cuttings and seeds.
Oncoba spinosa Forsk.	Bride of the desert; native of Arabia.	Small bushy tree.	Seeds
Peltophorum ferrugineum Benth.	The Rusty shield bearer; native of Ceylon.	Big tree with feathery pinnate leaves	Easily propagated from seed.
Peltophorum inerme (*Caesalpinia inermis* Naves)	The Rusty shield bearer or copperpod; Native of Ceylon and Andamans.	Tall tree. Very dense and dark foliage.	By seed.
Plumeria acutifolia Poir.	The pagoda tree or Firangi-pani. Native of Brazil.	A small low-spreading tree; semi-succulent with milky latex. Deciduous in nature.	Propagated usually by cuttings or layers. Much less by seed since fruiting is rare. Good for planting on Lawns.

Contd.

1	2	3	4
Plumeria alba L.	Firangipani Native of India.	Small dwarf tree having clusters of dark green ovate elaves.	Propagated by cuttings. There are a number of hybrid Plumerias.
Plumeria rubra L.	The Pagoda tree or Firangipani. Native of Brazil.	A small low-spreading tree; Semi-succulent with milky latex. Deciduous in nature.	*P. rubra* L. has crimsom flowers.
Poinciana regia Bojer.	The flame tree or Gulmohar. Native of Madagascar.	Large deciduous tree with spreading crown. Quick growing.	Easy to propagate from seed. Can be grown on lawn or to form an avenue.
Pongamia glabra Vent.		Dwarf deciduous tree with trifloliate leaves like of Shisham. Flowers in leaf-condition.	Raised from seeds.
Pterocarpus indicus Willd.	Native of Andamans	Tall handsome tree with a round spreading crown. Branches long drooping. Leaves pinnate.	Raised from seeds
Pterocarpus echinatus Pers.	Native of Philippines	Medium-sized tree.	-do-

1	2	3	4
Rhododeudron arboreum Sm.	Native of Himalayas	An evergreen small tree; straight growing.	Is a delicate species usually propagated by cutting or grafting.
Saraca declinata Miq.	Native of Sumatra	Small tree. Head of flowers on stem and main branches.	By seed.
Saraca indica Linn.	The Ashok tree.	An evergreen slow growing, medium tree.	Propagated by seed. Good for planting on lawn for flowers or as an avenue tree.
Schizolobium excelsum Vog.	Native of Brazil	Large quick growing tree with feathery bipinnate leaves. Flowers on large erect sprays when tree is bare.	From seed.
Sesbania grandiflora Poir.		Small, quick growing tree.	From seed.
Solanum grandiflorum Ruiz. et Pavon	Large flowered, Night shade Potato tree. Native of S. America	Small tree 10-15 m high with large leaves.	Propagated from seed and cuttings.
Spathodea campanulata Beauv.	The Tulip tree or the Fountain tree. Native of Western Tropical Africa.	Tall erect deciduous tree.	Propagated by seeds or cuttings. Planted for shades, ornament and avenue tree.

Contd.

1	2	3	4
Spathodea nilotica Seem.	Tnlp Tree	Small tree with bright flowers.	
Sterculia colorata Roxb.	Native of Ceylon	A moderate-sized tree, deciduous in nature. Stout stemmed.	Propagated by seed. Good for planting on lawns.
Sterculia foetida L.	Wild Almond or Poon Tree.	Tall straight tree with horizontal branches.	By seed.
Tabebiva rosea DC.	Native of Mexico	Small erect tree, palmately 5 leaved.	Propagated by seed.
Tabebuia spectabilis Nichols	Native of Venezuela	Small tree, when leafless in flower.	Propagated by seed.
Terminalia arjuna Bedd.	The Arjun Tree	Tall evergreen tree with smooth grey bark. Leaves oblong.	Propagated by seed.
Thespesia populnea L.	The Portia tree.	Small evergreen tree.	Propagated easily by seed or cuttings. Good roadside or avenue tree.
Wrightia tinctoria R. Br.	Dudhi	Small tree with ivory white stem having red flowers scattered among leaves.	By seed.
Stenocarpus sinuatus Endl.	Tulip tree of Queensland. Native of Australia.	Tall erect tree.	By seed.

1	2	3	4
		E. *Foliage shrubs*	
Acalypha hamiltoniana Hort.	—	Low bushy shrub 1m-1.5m high	By cuttings, stands clipping well. Suitable for hedges and clipping.
A. godseffiana Mast.	—	Shrub about 30cm-1m high, bushy in nature	By cuttings, stands clipping well. Good for ornamental hedges.
Aralia filiciolia Hort.	—	Shrub of medium height upto 1.5m	Propagated by cuttings, seeds. Moisture and shade needed. Good for conservatories.
Codiaeum croton (Sp. not mentioned as there are several)	—	Evergreen shrubs utpo 2.5m tall.	By planting cuttings or layers. Always kept on warm places. Grown usually in hot houses. Near walls and for borders.
Cycas circinnalis L.	Sago Palm	An evergreen slow growing species with a crown at top.	By suckers obtained from the base of the plant. For planting on lawn.
Dracaena reflexa Lam.	—	An evergreen plant	By seeds or cuttings of main stem. Planted horizontally. For planting near buildings or in hot houses.
Muehlenbeckia platyclados Meissn.	Centipede plant	A deciduous plant, wiry, dwarf.	By cuttings. A good pot plant.
Pandanus sanderi Hort.	Screw pine	An evergreen shrub, sometimes reaching great heights.	By suckers. Near ponds or lakes. Makes good clumps.

Contd.

1	2	3	4
Agave sp.	Sisal	An evergreen shrub	By suckers. For hedges, variegated varieties for planting on lawns.
Sansevieria zeylenica (Jacq.) willd.	Bowstring Hemp.	Perennials, evergreen	By planting suckers. Good for planting on lawns.
Sansevieria cylindrica	—	Perennials, evergreen	By planting suckers. Good for planting on lawns.
Yucca gloriosa L.	Spanish dggger	Green house shrub, hardy, evergreen.	By planting suckers, protection during severe cold weather. Good for planting on lawns.
		F. *Flowering shrubs*	
Bauhinia galpinii N.E.Br.	Native of South Africa	Large spreading evergreen shrub about 1.5m-2.5m or more.	By cuttings. Needs sunny moist position. Good for shrubbery or as a pot plant.
Beloperone oblongata L.	—	Handsome small evergreen shrub about 1m-1.25m high.	By cuttings inserted single in pots or by seed. Grown as a pot plant.
Caesalpinia pulcherrima Sw.	The Peacock flower	Large handsome deciduous shrub 2m-3m high.	Propagated from seed. Responds to prunning and makes bushy growth when cut regularly. Suitable for hedges and for shrubbery.

1	2	3	4
Cestrum nocturnum L.	The Night Blooming Jasmine.	An evergreen straggling shrub 1.5-2 m high.	By cutting of side shoots. Can be trained on walls, pillars, roofs of houses etc. Pot or bed plant.
Clerodendron main *C. fragrans* Vent.	Glory tree. Native of China,	Semi-evergreen flowers white, crimson shaded, fragrant,	By cutting
C. kaempferi Sieb.	Large terminal clusters of brilliant scarlet flowers.	Evergreen or semi-evergreen species, shrubby in nature. Height varying.	Propagated by cuttings of branches or side shoots or from seed. Most like partial shade. Shoots should be cut back after flowering. Good for pot plant or for planting on lawns, or near corners of walls or houses.
C. fallax Lindl.	Flowers bright scarlet in	Evergreen.	-do-
C. phlomides Linn.	summer. White flowers.	Semi-ever-green	-do-
C. paniculatum		Evergreen.	-do-
C. thomsoniae		Belfour evergreen.	-do-

Contd.

1	2	3	4
Daedalcanthus nervosus (Vahl.) T. Anders.	—	Hardy evergreen shrub about 60cm-1m high.	Cuttings of young shoots inserted in sandy pots. Good as pot plant or as an ornamental hedge.
Hibiscus mutabilis L.	The Chinese Rose	Hardy deciduous species reaching the height of about 2.5m. Fast growing.	Propagated mostly by cutting or layers or by seed. Should be planted in semi-shaded places. Thinning of dead branches after flowering.
H. roasasinensis L.	The Shoe flower	An evergreen species. Tall shrub reaching 2.5m-3m	By cutting, layering or by seed. Needs sunny places. Thinning necessary before monsoon.
Holmskioldia sanguinea Retz.	The Cup & Saucer plant.	A semi-deciduous species reaching height of about 2.5m, much branched.	Can be easily propagated by cutting. Should be pruned after flowering. Can be grown on lawns or as a border plant.
Ixora			
I. coccinea L.	Fowers during winter. Bright orange scarlet.		
I. parviflora Vahl.	Bright white flowers, throughout the year.		

1	2	3	4
I. rosea Wall.	Rose coloured flowers during winter.	Evergreen shrubs of varying sizes	Propagated from cuttings of young firm side shoots planted singly. During growth, should be kept in warm shady place. When at rest keep in light. Pruning after flowering is very necessary. Grown as pot or tub plant.
I. chinensis Lamk.	Reddish flowers in condensed terminal cymes in monsoons.		
I. undulata Roxb.	Sweet scented white flowers on terminal corymbs in March-April.		
I. lutea Hutch.	Yellow flowers throughout the year.		
Lagerstroemia indica L.	Crepe Myrtilles	A deciduous bushy shrub about 2m-2.5m tall, leaf shedding in winter.	Propagation by cuttings and layers. Requires sunny places. Good for growing on lawns. Would make a good hedge plant.
Myrsine erecta	—	An erect deciduous shrub about 1m-1.5m high hardy in nature.	Propagated by cuttings. Useful for hedge.

Contd.

1	2	3	4
Mussaenda erythrophylla Schum.	—	Evergreen flowering shrub about 30 cm high.	Needs to be sheltered from Western sun. Good pot plant.
Nyctanthes arbortristis L.	—	A hardy large shrub with white bark. Deciduous reaches upto 3m.	Propagated easily by seed or from cuttings. Needs semi-shade. Good for planting in house gardens.
Poinsettia pulcherrima Grah.	—	Tall deciduous shrub with white bark. About 2m to 3m high with a rapid growth.	Easily propagated by cutting. Rahter delicate when poted should not be disturbed. Should be cut after flowering. Good for making hedge.
Tabernaemontana coronaria Willd.	—	Evergreen shrub about 1.5m high.	Easily propagated by layering. Good for lawns or for borders.
		G. *Palms*	
Areca alba Bory *A. lutescens* Wendl. *A. triandra* Roxb.	—	Arecas are handsome palms growing fairly tall.	Propagated by seed. Young plants useful for table decoration. Useful for tubs or for planting on lawns.
Arenga sacchafers Labill.	Sugar palm	Beautiful tall species.	Propagated by seed. A good avenue plant.
Caryota urens L.	Malabar Sago Palm or Wine Palm	Large species reaching the height of about 20m under natural conditions.	Propagated by seed. Good for planting on lawn. Young plant used as pot plant.

1	2	3	4
C. australis R. Br.	Talipot palm	A fan palm growing to great height in nature. Very slow growing.	Propagated by seed. Good for planting on lawn. Young plant a good pot plant.
Hyophorbe		Massive elegant palms with bottle shaped caudicles.	Propagated by seed. Good for planting on lawn.
H. americaulis Mart.			
H. verschaffettii Wendl.		Attaining medium height.	
Kentia	—	A handsome genus with about a dozen cultivated species. Decumbent when young.	Propagated by seed. Very valuable pot plant for decoration inside houses or shade gardens.
Licuala grandis Wendl.	—	Hardy palms, small, very ornamental genus.	Propagated by seed. A very attractive beautiful palm usually used for table decoration.
Pritchardia pacifica Seem.	—	Very ornamental species.	Propagated by seed. A very attractive beautiful palm usually used for table decoration.
Martinezia		Highly ornamental palms.	Propagated by seed. Good as a pot plant for decoration inside the house.
M. erosa Lindl.			
M. caryotaefolia HBK			
M. truncata Brogn.			
Oredoxa	Royal palm	Tall palm growing straight.	Propagated by seed. Need to be protected from winds. Good
O. regia	Cabbage		

Contd.

1	2	3	4
O. oleracea	Palm		trees for avenues. Good as pot plants when young.
Phoenix *P. roebelinii* O' Brien.	—	Medium palm, growing straight, highly ornamental.	Propagated by seed. Good as a pot plant for indoors.
Raphis *R. flabelliformis* L' Her, *R. humilis* Blume	Ground Rattan Palm.	Dwarf palms, rattan like with slender stems.	Propagated mainly by the division of suckers. Good for pot cultures and bushy clumps.
		H. *Climbers*	
Allamanda cathartia Linn.	Willow leaved Allamanda	A hardy evergreen climber.	By cuttings or grafts. As a climber on walls or to form stands or canopies. Good tub plant.
A. violacea Gradn.	—	—	By layering only. As a climber on walls or to form stands or canopies. Good tub plant, not so popular, but needs encouragement.
Beaumontia grandiflora Wall.	Nepal Trumpet flower.	A hardy evergreen climber reaching good height.	By layering or by cutting. Good for walls or for roofs of pot houses or for trellises.
Bignonia magnifica Bull.	—	Tender vigorous evergreen climber.	By cuttings planted in sand. For walls of houses.

1	2	3	4
B. unguiscati Linn.	Native of tropical America.	—	By cuttings planted in sand.
B. venusta Ker.	Golden shower Native of Brazil.	—	By layering
Bougainvillea spectabilis Willd.	Native of Brazil.	Climbing deciduous plant. Quite woody spiny.	By inserting tubercles obtained from stem in soil or by layering. Can be trained on walls or on canopies or roofs.
Chonemorpha macrophylla Don.	—	Large woody evergreen climber.	By layering, for training on walls and roofs.
Jacquemontia violacea	—	A slender deciduous climber.	By cuttings. Good for training on walls.
Jasminum sp.	—	Climbers or trailers, evergreen.	By cuttings and layers. Need trimming regularly. Several species known. Good climbers to cultivate for their flowers. Can go on walls, canopies or hedges.
Passiflora		Evergeen slender climber.	By cuttings and layers. Can be trained on walls, canopies and trellises.

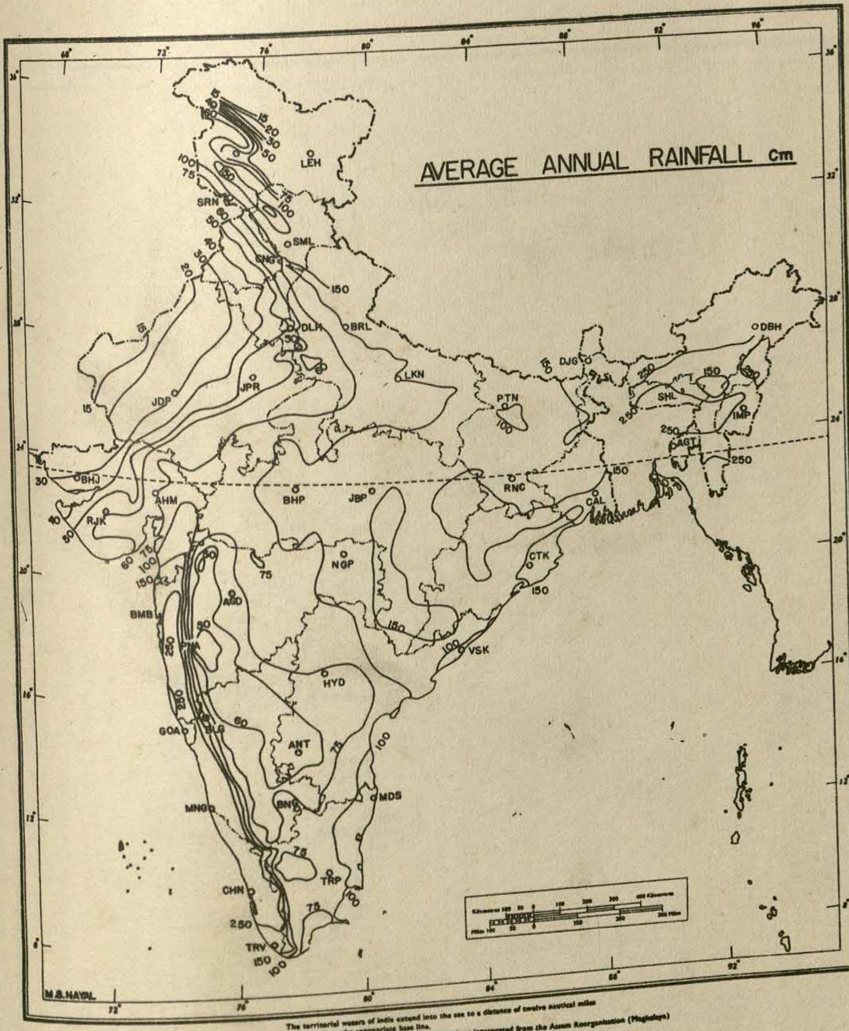
Contd.

1	2	3	4
Petrea volubilis Jacq.	A native of tropical America.	A deciduous climber.	By cuttings and layers. Can be trained on walls, canopies and trellises.
Thunbergia fragrans Roxb.	—	Evergreen climber which tends to spread	By layering. Can be trained on walls, canopies and trellises.
Vallaris heynei Spreng.		Twining shrub.	By suckers, needs regular trimming. Good for covering walls of compounds because of its rapid growth.
		I. *Ferns*	
Adiantum	Maiden Hair Ferns	About 20 species of cultivated small ferns.	Either by spores or by the division of clumps. Very easy to cultivate.
Alsophila	The Grove Fern.	A genus of ornamental tree ferns with an erect stem. Several species cultivated.	Propagation by spores. Needs heavy watering and moisture around and partial shade. Good plants for conservatory.
Angiopteris erecta Hottm.	Turnip Fern.	Large growing fern, fairly tall.	Propagated usually by off-sets. Usually suited for high altitudes. Good tub plant for conservatory.
Asplenium nidusavis Hort. and other sps.	Bird's Nest Ferns	Different species having different habits.	Propagation by spores. Needs care for good development. Good pot plant for tubs, very decorative.

1	2	3	4
Blechnum occidentale	Brazilian Tree Fern	Erect tree fern; slow growing.	Propagated by spores. Needs humid weather and shade. Very decorative low fern for growing indoor.
Davallia	Hare's Foot Fern or Bear Foot Fern	Handsome group of several species with scaly creeping rhizome.	By the division of rhizomes or by spores. Good as tub plant or for growing baskets.
Gymnogramia	Golden Fern or Silver Fern	A group of very attractive tall or dwarf ferns.	By spores. Being delicate ferns need utmost care. Good as pot plants for ferneries.
Nephrodium	—	Large genus of several cultivated hardy and handsome species.	Propagation by spores or by division of fronds. Being hardy do not need much care. Useful
Nephrolepis	—	An extensive genus of hardy attractive ferns.	By spores or the divisions of stolons bearing young plants. Do not need much careful handling. Useful for decoration in verandhas and even outside.
Polypodium	—	Large genus with many ornamental species.	By spores. Useful for decoration in verandahs and even outside.
Pteris	—	Large genus with about a dozen cultivated attractive species.	Propagated usually by spores. Excellent pot plants.

10 *Unusual Trees*

Species	Pop. name	Habit	Method of propagation
Adansonia digitata	Monkey Bread tree	Giant tree with thick smooth trunk, base broad.	By seed
Careya arborea		Forest tree, copper red; leaves appear pricking in October.	By seed
Couropita guianensis	Cannon-ball tree. Native of Tropical S. America	Large tree, fruits globular about man's head.	By seed
Cycas revoluta	China Fern tree	Tree with palm like leaves	Bulbils.
Ficus krishnae	Krishna's butter cup	Small tree with folded leaves joined at base which appear like contameri of icecream.	
Ginkgo biloba	Maiden hair tree. Native of China	A living fossil with beautiful foliage.	By seed
Kigelia pinnata	Native of tropical W. Africa	Medium-sized, spreading, bearing long pendulous raceme of fls.	By seed
Parmentiera cereifera	Candle tree. Native of Tropical America.	Small tree. Leaves light green. Fruit cylindrical, candle like on stem and branches twice a year.	By seed
Ravenala madagascariensis	Traveller's tree	Tree appearing like gigantic ladies hand fan.	
Trevesia moluccana	Tropical Native of Moluccas.	Small tree; leaves palmate spreading.	



AVERAGE ANNUAL RAINFALL Cm

Based upon Survey of India map with the permission of the Surveyor General of India.

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the Assam Reorganisation (Meghalaya) Act, 1969, but has yet to be verified.
Meghalaya is an autonomous state within the state of Assam.

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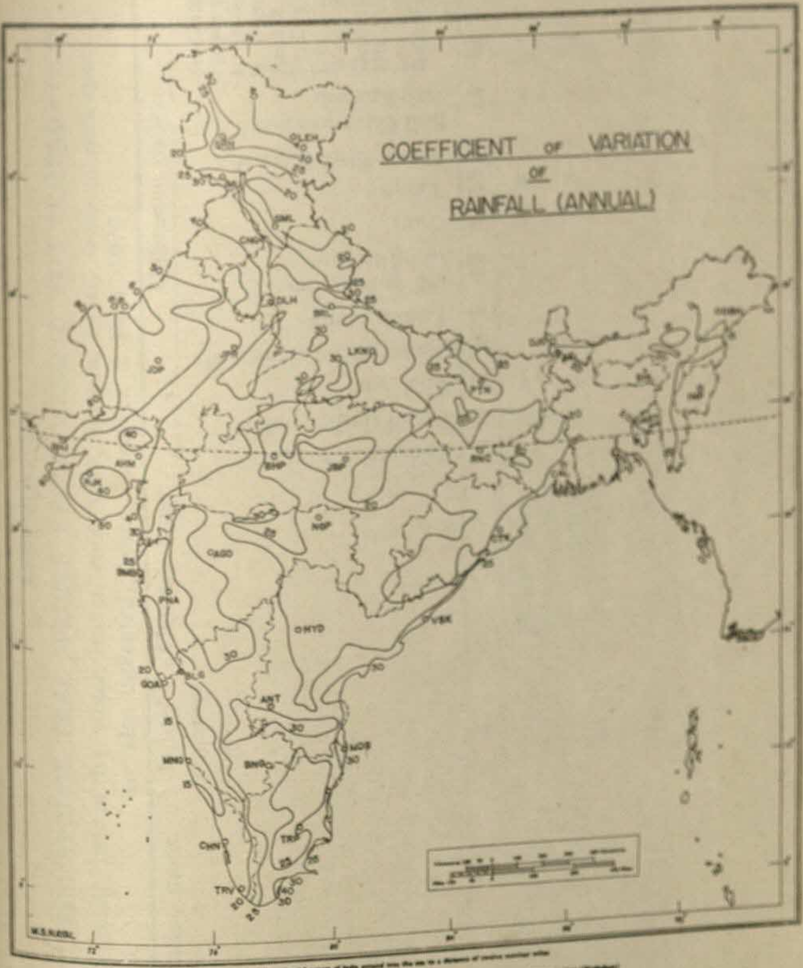
COEFFICIENT OF VARIATION OF RAINFALL (ANNUAL)



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APPENDIX VI

MULTIPURPROSE TREE SPECIES RECOMMENDED FOR PROPAGATION

(Versatile uses of the wood, leaves, root, bark, flowers, fruits, seeds of each species are also indicated) (after Srivastava & Pant, 1979.)

Sl. No.	Scientific name	Trade/ common name	Climatic zone	Utilization pattern										
				Industrial timber	Small timber poles	Fuel wood	Fodder/feed, leaf/pods	Edible fruits	Oil bearing seeds/ wood/leaves	Gum	Tanin	Shade/Ornamental	Soil Conservation/ stabilization	Medicinal value: Flower-F, Leaf-L, Seed-S, Bark-B, Gum-G, Root-R, Fruit-Fr, Dry Flower-DF, Plant-P, Wood-W, Oil-O, Decoet of Bark-DB, Decoet of Leaves-DL, Root Bark-RB
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	*Acacia modesta*	Phulai	Sub-tropical		x	x				x	x		x	G.
2.	*Acacia senegal*	Kumta	Dry-tropical		x	x				x	x		x	G.
3.	*Acacia cupressiformis*		Dry-tropical		x	x	x			x	x		x	B.G.
4.	*Acacia nilotica* ssp. *indica*	Babul	Dry-tropical			x	x						x	B.
5.	*Acacia catechu*	Khair	Dry and moist tropical	x	x	x					x		x	B.L.

Contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5A.	*Acacia chundra*	Lal-khair	Dry-tropical	x	x	x					x		x	B.
6.	*Acacia radiana*	Vilayati-kikar	Dry-tropical		x	x					x		x	B.
7.	*Acacia alurina*	Pahari-kikar	Dry-tropical		x	x					x		x	B.G.
8.	*Acacia auriculiformis*	Sonajhuri	Dry and moist tropical		x	x					x		x	B.G.
9.	*Aegle marmelos*	Bael	Dry-tropical			x		x	x	x	x	x	x	F.R.
10.	*Aesculus indica*	Horse-chestnut	Temperate, Subtropical		x		x	x	x			x	x	F.B.O.
11.	*Ailanthus excelsa*	Maharukh	Tropical moist, dry-tropical			x						x	x	
12.	*Albizia lebbek*	Kokko	Dry and moist tropical		x		x				x	x	x	P.B.S.R.L.
13.	*Albizia procera*	Safed-siris	Tropical moist	x	x							x	x	L.
14.	*Alnus nitida*	Alder	Temperate		x						x	x	x	
15.	*A. nepalensis*	Alder	Temperate, subtropical		x						x	x	x	B.
16.	*Anacardium occidentale*	Cashew	Dry tropical coastal		x	x		x	x			x	x	B.R.F.
17.	*Artocarpus integrifolia*	Kathal	Tropical moist		x			x			x	x	x	L.R. Flower
18.	*A. lakoocha*	Lakoocha	-do-											
19.	*Arundo donax*	Baranal	Subtropical	x	x							x	x	Rhizome
20.	*Azadirachta indica*	Neem	Dry and moist tropical	x			x		x	x		x	x	B.L.G.D.F.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
21.	*Bauhinia chinensis*	Kanchan (Kachnar)	Sub-tropical, tropical											P
22.	*B. retusa*	-do-	-do-		x		x			x		x	x	P.G.
23.	*B.* species	-do-	-do-		x		x			x		x	x	E.P.G.S.L.
24.	*Boswellia serrata*	Salai	Dry tropical	x	x	x				x		x	x	G.
25.	*Cassia fistula*	Amaltas	Tropical moist			x					x	x	x	Fr. RB,
											x			F.L.R.
26.	*C. siamea*	Rajbrikh	-do-	x		x						x	x	L.
27.	*C. auriculata*	Tarwar	-do-		x		x				x	x	x	B.R.L.F.S.
28.	*Casuarina equisetifolia*	Casuarina	-do- and coastal region	x	x	x	x		x			x	x	B. DL.
29.	*Castanopsis* species	Chestnut	Temperate	x							x	x	x	S.
30.	*Castanea sativa*	Sweet Chestnut	Sub-tropical	x			x	x			x	x	x	L.
31.	*Celtis caucasica*	Celtis	Temperate, Subtropical.	x	x	x	x	x				x	x	F.S.
32.	*Cornus oblonga*	Indian cornel	Subtropical	x	x							x	x	
33.	*Corylus colurna*	Bhotiabadam	Temperate					x				x	x	Nuts.
34.	*Cordia dichotoma*	Lasora	Dry tropical	x			x	x			x	x	x	F.B.L. DB.
35.	*Cordia rothii*	Lasora	-do-	x			x		x			x	x	DB.
36.	*Cupressus torulosa*	Cypress	Temperate, sub-tropical	x	x				x			x	x	
37.	*C. cashmeriana*	-do-	-do-		x							x	x	Tubers.

Contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
38.	*Dalbergia sissoo*	Sissoo	Tropical moist	x	x			x	x		x	x	x	L.R.W.
39.	*D. latifolia*	Rosewood	-do-	x	x						x	x	x	P.
40.	*Dendrocalamus strictus*	Bamboo	Dry tropical, Tropical moist	x	x		x	x					x	L.
41.	*Duabanga sonneratioides*	Lampati	Sub-tropical, Trop. moist.	x	x			x				x	x	G.
42.	*Eucalyptus camaldulensis*	Eucalyptus	Dry and moist tropical	x					x	x	x	x	x	
43.	*E.* species	Eucalyptus	Temperate, sub-tropical, dry and moist tropical	x	x	x			x	x	x	x	x	L.R.
44.	*Emblica officinalis*	Amla	Moist & Dry tropical		x	x			x	x	x	x	x	F.R.S. Fl.
45.	*Ficus* species	Figs	Sub, Dry and moist tropical		x	x	x		x			x	x	L.B.S.R.F.
46.	*Ficus glomerata*	Gular	Sub-tropical		x	x	x					x	x	B.R.L.F.
47.	*Grevillea robusta*	Silver Oak	Sub-tropical		x	x	x			x	x	x	x	
48.	*Grewia optiva*	Dhanan	Temperate, sub-tropical		x		x				x	x	x	
49.	*Gmelina arborea*	Gamari	Tropical moist	x	x	x	x					x	x	L.P.
50.	*Holoptelea integrifolia*	Kanju	Tropical, moist and dry tropical	x	x	x	x	x	x			x	x	B.
51.	*Juglans regia*	Walnut	Temperate	x			x		x			x	x	B.L.F.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
52.	*Kydia calycina*	Pula	Tropical moist	x	x	x	x			x		x	x	L.
53.	*Lawsonia alba*	Henna	Dry tropical		x						x	x	x	B.L. DL. Fl.
54.	*Litchi chinensis*	Benthal	Subetropical					x				x	x	F.L.
55.	*Lagerstroemia* spp.	Benteak	Tropical moist	x	x	x	x			x	x	x	x	
56.	*Leucena leucophala*	Tiora kadam	Dry tropical		x	x						x	x	B. Plant
57.	*Madhuca latifolia*	Mahua	Dry tropical	x		x	x	x	x			x	x	B.S. Flower
58.	*Mangifera indica*	Mango	Sub-tropical Tropical	x	x		x	x		x		x	x	L.F.S.B.
59.	*Mesua ferrea*	Mesua	Tropical moist	x	x	x		x	x	x	x	x	x	F.B. Unripe Fr.
60.	*Melia azedarach*	Bakain, (Persian-lilac)	-do- and Dry tropical	x	x	x	x	x			x	x	x	DL. B.L.
61.	*Michelia oblonga*	Champ	Sub-tropical	x	x	x						x	x	B. RB. F. Fr.
62.	*M. excelsa*	Champ	-do-	x	x							x	x	B.F.
63.	*Mitragyna parviflora*	Kaim	Moist tropical	x	x	x					x	x	x	B.R.
64.	*Morus laevigata*	Bola	Sub-tropical	x	x		x	x				x	x	
65.	*M. serrata*	Mulberry	-do-	x	x		x					x	x	
66.	*M. alba*	-do-	Tropical moist	x	x		x	x			x	x	x	
67.	*Parkinsonia aculeata*	Vilayati Babul	Dry tropical			x	x	x				x	x	
68.	*Phoenix dactylifera*	Khajur	-do-		x			x				x	x	Fr. S.
69.	*Pinus gerardinana*	Chilgoza Pine	Temperate			x		x		x		x	x	
70.	*P. roxburghii*	Chir	Sub-tropical	x	x	x			x	x	x	x	x	

Contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
71.	*Platanus orientalis*	Chinar	Temperate		x							x	x	B.L.R.
72.	*Planchonella littoralis*	Lamba-patti	Tropical moist				x					x	x	L.
73.	*Pongamia pinnata*	Karanji	Dry tropical		x	x	x		x			x	x	O.L. RB.BF.
74.	*Populs alba*	Poplar	Sub-tropical	x	x	x	x					x	x	B.
75.	*P. ciliata*	-do-	-do-	x	x	x	x					x	x	B.
76.	*P. nigra*	-do-	-do-	x	x	x	x				x	x	x	L.
77.	*P. euphratica*	-do-	-do-	x	x		x					x	x	B.
78.	*Prosopis chilensis*	Vilayati-kikar	Dry tropical	x	x					x	x	x	x	
79.	*P. cineraria*	Jhand	-do-		x	x	x			x		x	x	W.
80.	*Prunus persica*	Khubani	Temperate		x	x		x	x	x	x	x	x	F. W.
81.	*P. armeniaca*	-do-	-do-		x	x		x				x	x	
82.	*P. cerasoides*	Padam	-do-					x	x	x	x	x	x	B. Branches
83.	*Peltoforum pterocarpum*	Sejan	Sub, dry and moist tropical	x	x		x					x	x	B.
84.	*Pterygota alata*	Narikel	Tropical moist	x	x	x			x			x	x	S.
85.	*Putranjiva roxburghii*	Putranjiva	Tropical, Sub-tropical	x	x		x		x			x	x	L.
86.	*Quercus floribunda*	Indian Oak	Temperate	x	x	x	x				x	x	x	S.
87.	*Q. glauca*	Phaxonj	-do-		x	x	x				x	x	x	S.
88.	*Q. incana*	Banj	-do-	x	x	x	x				x	x	x	(acorns)
89.	*Salix alba*	White willow	-do-	x	x	x	x				x	x	x	B.

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90.	*S. babylonica*	Weeping willow	-do-	x	x	x	x					x	x	L.B.
91.	*S. fragilis*	Kashmir willow	Temperate	x	x	x	x					x	x	F.L.
92.	*Salvadora oleoides*	Pikhuva	Dry tropical	x	x	x	x			x	x	x	x	R.F. Fr.
93.	*Salmalia insignis* (*Bombax insigne*)	Didu	Tropical moist	x	x	x	x				x	x	x	
94.	*S. malabarica* (*B. ceiba*)	Semul	Tropical moist	x	x				x			x	x	S.O.W.R.
95.	*Santalum album*	Sandal-wood	Dry tropical	x										L. Fr.
96.	*Saraca indica*	Ashok	Tropical, Sub-tropical and dry tropical		x		x					x	x	B.L.F.
97.	*Schleichera oleosa*	Kusum	Tropical	x	x	x		x	x	x	x	x	x	F.FR.
98.	*Shorea robusta*	Sal	Tropical moist	x	x	x			x	x	x	x	x	
99.	*Spondias pinnata*	Amra	Sub-tropical, tropical & moist trop.	x			x			x		x	x	
100.	*S. mombin* spp.	Amra	-do-				x					x	x	L.S. Fr.
101.	*Sterculia urens*	Karaya	Dry tropical	x	x	x			x	x	x	x	x	S.B.L.R.
102.	*S. villosa*	Udal	-do-	x	x	x		x		x		x	x	
103.	*Stereos permum personatum*	Padri wood	Sub-tropical, Tropical moist	x	x		x					x	x	R.L.F.B.
104.	*Stereospermum suaveolens*	-do-	-do-	x	x	x	x					x	x	F. B. DB.

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105.	*Swietenia mahagoni*	Mahogoni	-do-	x	x					x	x	x	x	
106.	*Syzygium cumini*	Jamun	-do-	x	x	x	x	x	x		x	x	x	F. Fr.
107.	*S. jambolana*	-do-	-do-					x	x		x	x	x	F. Fr.
108.	*Tamarindus indica*	Imli	Dry tropical	x	x				x	x	x	x	x	L. F.
109.	*Tectona grandis*	Teak	Dry and moist tropical	x	x	x	x				x	x		W.S.F.B.
110.	*Terminalia arjuna*	Arjun	Tropical	x	x	x	x				x	x	x	B. L. Fr.
111.	*T. bellirica*	Bahera	Tropical moist	x	x	x	x		x	x	x	x	x	Fr. B.W.
112.	*T. bialata*	White chuglam	-do-	x	x					x	x	x	x	B.
113.	*T. tomentosa*	Laurel	Tropical	x	x			x		x	x	x	x	B.
114.	*T. chebula*	Myrabolan wood	-do-	x	x			x		x	x	x	x	B. Fr.
115.	*T. myriocarpa*	Hollock	Tropical moist	x	x	x					x	x	x	B.
116.	*T. manii*	Black chuglam	-do-	x	x	x						x	x	W.
117.	*Ulmus wallichiana*	Elm	Temperate	x	x	x	x					x	x	
118.	*Vateria indica*	Vellapiney	Tropical moist	x	x							x	x	B. Fr.
119.	*Vitex altissima*	Milla	-do-	x	x	x						x	x	
120.	*V. penduncularis*	Nagphani	-do-	x	x	x						x	x	L. B. RB.
121.	*V. pinnata*	-do- Tropical	-do- and Tropical	x	x							x	x	B. L. DB.
123.	*Xylia xylocarpa*	Irul	Tropical			x			x			x	x	Dect. B.O.
124.	*Zizyphus jujuba*	Ber	Sub-tropipical	x				x	x		x	x	x	S.L. Fr.

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